UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

In response refer to:
2009/01239

April 3, 2009

Kathleen A. Dadey, Ph.D.
Chief, California South Branch
U.S. Army Corps of Engineers
1325 J Street
Sacramento, California 95814-2922

Dear Dr. Dadey:

This document transmits NOAA's National Marine Fisheries Service's (NMFS) biological opinion (Enclosure 1) based on our review of the proposed construction and operation of the Non Physical Barrier (NPB) as part of the South Delta Temporary Barriers Program (TBP) in San Joaquin County for the 2009 operational season by the California Department of Water Resources (DWR), and its effects on Federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), threatened Central Valley spring-run Chinook salmon (*O. tshawytscha*), threatened Central Valley steelhead (*O. mykiss*), and threatened Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*) and the designated critical habitat of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead and the proposed critical habitat for Southern DPS green sturgeon in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq*., Enclosure 1). The U.S. Army Corps of Engineers (Corps) originally requested formal consultation regarding the effects of the South Delta TBP on December 11, 2007, upon listed salmonids, green sturgeon, and their designated and proposed critical habitats. NMFS issued a biological and conference opinion for the South Delta TBP on May 5, 2008. NMFS received a request from the Corps to initiate consultation to amend the South Delta TBP biological opinion on March 20, 2009, to include the construction and operation of an experimental bubble curtain in 2009 in lieu of installing the Head of Old River fish barrier for the 2009 operations season.

This biological opinion is based on information provided by the applicant, DWR, electronically on March 5, 2009, the project's biological assessment provided electronically by DWR on March 9, 2009, telephone conversations between NMFS staff and representatives from DWR, and a literature review completed by NMFS staff. A complete administrative record of this consultation is on file at the NMFS Sacramento Area Office.

Based on the best available scientific and commercial information, the biological opinion concludes that South Delta TBP, including the construction and operation of the NPB program, is not likely to jeopardize the continued existence of the above listed species or adversely modify or destroy proposed and designated critical habitats. NMFS also has included an incidental take statement with reasonable and prudent measures and non-discretionary terms and conditions that are necessary and appropriate to minimize incidental take of listed salmonids associated with the project. The section 9 prohibitions against taking of listed species and the terms and conditions in the Incidental Take Statement of this biological opinion will not apply to the Southern DPS of North American green sturgeon until a final section 4(d) rule becomes effective.

Also enclosed are Essential Fish Habitat (EFH) Conservation Recommendations for Pacific salmon as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSA) as amended (16 U.S.C. 1801 *et seq.*; Enclosure 2). This document concludes that construction of the South Delta TBP, as amended, will adversely affect EFH of Pacific salmon in the action area and adopts the ESA reasonable and prudent measures and associated terms and conditions from the biological opinion as well as the recommendations in Appendix A of Amendment 14 to the Pacific Coast Salmon Plan as the EFH Conservation Recommendations.

Section 305(b)4(B) of the MSA requires the Corps to provide NMFS with a detailed written response within 30 days, and 10 days in advance of any action, to the EFH Conservation Recommendations, including a description of measures adopted by the Corps for avoiding, minimizing, or mitigating the impact of the project on EFH (50 CFR 600.920[j]). In the case of a response that is inconsistent with NMFS recommendations, the Corps must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the proposed action and the measures needed to avoid, minimize, or mitigate such effects.

We appreciate your continued cooperation in the conservation of listed species and their habitat, and look forward to working with you and your staff in the future. If you have any questions regarding this document, please contact Mr. Jeffrey Stuart in our Sacramento Area Office, 650 Capitol Mall, Suite 8-300, Sacramento, CA 95814. Mr. Stuart may be reached by telephone at (916) 930-3607 or by Fax at (916) 930-3629.

Sincerely,

for Rodney R. McInnis
Regional Administrator

Enclosures (2)

cc: Copy to file: **151422SWR2007SA00142**
NMFS-PRD, Long Beach, CA.
Mark Holderman, Chief, Temporary Barriers and Lower San Joaquin, California Department of Water Resources, 1416 9th Street, Sacramento, CA 95814
Ryan Olah, U.S. Fish and Wildlife Service, Cottage Way, Sacramento, California

Enclosure 1

BIOLOGICAL AND CONFERENCE OPINION

ACTION AGENCY: U.S. Army Corps of Engineers, Sacramento District

ACTIVITY: Reinitiation of formal consultation for the South Delta Temporary Barriers Project

CONSULTATION CONDUCTED BY: Southwest Region, National Marine Fisheries Service

FILE NUMBER: **151422SWR2007SA00142**

DATE ISSUE: **April 3, 2009**

I. CONSULTATION HISTORY

On November 13, 2006, NOAA's National Marine Fisheries Service (NMFS) received a request from the State of California, Department of Water Resources (DWR) to extend the in-water work period for the removal of the temporary barriers in the South Delta beyond the November 30 date stipulated in the project description for the existing biological opinion.

On December 22, 2006, NMFS responded that it was unable to grant this extension since the existing biological opinion signed in 2001 had not analyzed the impacts of the project on the recently listed Southern Distinct Population Segment (DPS) of the North American green sturgeon (*Acipenser medirostris*) and the designated critical habitats of Central Valley spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*O. mykiss*).

On February 5, 2007, NMFS received a copy of a letter from the United States Army Corps of Engineers (Corps) indicating DWR's request to reinitiate section 7 consultation for the agricultural barriers portion of the South Delta Temporary Barriers Project (TBP, Corps permit number 200100121).

On February 28, 2007, NMFS received an additional request for reinitiation of section 7 consultation for the remaining portion of the South Delta TBP from the Corps, the Head of Old River fish diversion barrier (Corps permit number 200000696). NMFS staff conferred with DWR staff and determined that this was an error and that the entire TBP was intended as the subject of the section 7 consultation. DWR staff also indicated that they had not finished their biological assessment (BA) for this consultation at that time.

Subsequently, on April 2, 2007, NMFS received a corrected request for reinitiation of the TBP with a completed consultation package.

On May 31, 2007, NMFS responded in writing to the Corps that formal consultation for the South Delta TBP was initiated with the receipt of the April 2, 2007, final BA and consultation package.

On November 27, 2007, NMFS received a letter from the Corps requesting initiation of consultation for a 3-year extension of the Head of Old River TBP to cover the 2008 through 2010 operational seasons.

On December 11, 2007, NMFS received a letter from the Corps requesting initiation of consultation for a 3-year extension of the South Delta TBP from 2008 to 2010.

On May 5, 2008, NMFS issued a biological opinion for the continued operations of the South Delta TBP from 2008 to 2010.

On January 7, 2009, NMFS received a concept document for a temporary behavioral barrier to be installed at the Head of Old River from DWR. The concept paper described a 500-foot long bubble curtain to be installed at the Head of Old River during the spring of 2009 in place of the rock temporary barrier typically installed. The Head of Old River (HOR) barrier is currently not expected to be installed due to Delta smelt concerns.

On February 5, 2009, NMFS received an email from DWR updating the status of air bubble curtain project, *i.e.*, the "non-physical barrier concept"

On February 24, 2009, NMFS received Bowen *et al.* (2008) and other documents describing the proposed non-physical barrier (NPB) action.

On February 25, 2009, NMFS management and DWR management exchanged emails discussing the permit process for this action for the 2009 season.

On March 5, 2009, NMFS received an electronic copy of the letter and supporting documents sent to the Corps, Sacramento Office requesting an amendment to the South Delta Temporary Barriers Biological Opinion issued on May 5, 2008, to install the non-physical barrier at the Head of Old River during the spring of 2009.

On March 9, 2009, NMFS received from DWR, electronic copies via email the biological assessment for the proposed non-physical barrier.

On March 10, 2009, NMFS received a hard copy in the mail of the request by DWR to the Corps for an amendment to the 2008 South Delta Temporary Barriers Program Biological Opinion.

On March 20, 2009, NMFS received a request to initiate consultation for the NPB project in the South Delta as an amendment to the 2008 South Delta Temporary Barriers Program biological opinion from the Corps.

This biological and conference opinion analyzes the effects of the amended South Delta Temporary Barriers Project on Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, designated critical habitat for Central Valley steelhead, the Southern DPS of North American green sturgeon, and the proposed critical habitat for the Southern DPS of North American green sturgeon. A complete administrative record is located at the NMFS Sacramento Area Office.

II. DESCRIPTION OF THE PROPOSED ACTION

A. General Overview

1. Introduction

The South Delta TBP is an ongoing project which installs up to four rock barriers in channels located in the southern portion of the Sacramento - San Joaquin Delta near the cities of Tracy and Lathrop in San Joaquin County, California. The South Delta TBP was initiated in 1991 in response to a lawsuit filed by the South Delta Water Agency (SDWA) in 1982 against DWR. DWR agreed to install these barriers to ensure that local agricultural diverters within the SDWA did not experience adverse water level and circulation impacts caused by the State Water Project (SWP) and Central Valley Project (CVP).

The program installs three rock barriers in Old River near Tracy (ORT), Middle River (MR), and Grant Line Canal (GLC) near the Tracy Boulevard Bridge which are designed to act as flow control structures, "trapping" tidal waters behind them following a high tide. These barriers improve water levels and circulation for local South Delta farmers. The fourth barrier, the HOR barrier is designed to improve migration conditions for Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) originating in the San Joaquin River watershed during adult and juvenile migrations (*i.e.*, fall and spring) by "blocking" migratory movements into the Old River channel from the mainstem San Joaquin River (see Appendix B: Figures 1a and 1b).

The barriers are typically installed during the period between April and November to facilitate pumping by agricultural water diversions for irrigation purposes and to provide a measure of protection for anadromous fish species migrating through the San Joaquin River corridor. The spring installation of the HOR barrier is designed to reduce the loss of outmigrating San Joaquin River basin Central Valley fall-run Chinook salmon smolts by significantly decreasing their diversions down Old River, consequently reducing their entrainment at the SWP and CVP pumps. Central Valley steelhead also benefit from this protective action, although maybe not to the same extent as fall-run Chinook salmon because of their different emigration times.

The purpose of the fall HOR barrier is to improve dissolved oxygen (DO) levels in the San Joaquin River between the HOR barrier and Medford Island, 25.5 miles downstream. The barrier installation increases the volume of San Joaquin River flow passing downstream through the Port of Stockton and ameliorates the low DO sag that occurs there. The installation of the HOR barrier is believed to aid adult salmon upstream migration in the San Joaquin River basin.

The three agricultural barriers (ORT, MR and GLC) help control water levels upstream of the barriers so that agricultural pumps will have enough pump draft to operate efficiently during each tidal cycle. The channel sections upstream of the barriers will fill with water when the flood tide moves into the South Delta and overtops the barrier weirs. On the falling ebb tide, the water will be retained behind the barriers, maintaining sufficient depth to continue agricultural pumping without loss of service. Water quantities are not increased for the South Delta farmers; however, the availability of adequate pump draft and pumping efficiency is improved with the barriers in place.

Due to the high probability that the HOR barrier will not be installed in 2009 due to Delta smelt issues, DWR is proposing to test the effectiveness of a NPB at the Head of Old River in spring 2009 to meet the TBP HOR barrier objective of excluding outmigrating smolts from Old River while also minimizing the potential effects to Delta smelt. Under the existing design of the HOR barrier, a 200-foot-long rock barrier is constructed with approximately 12,500 cubic yards of rock and sand. In the spring, the barrier allows only minimal flow downstream through Old River and prevents downstream-migrating salmon smolts in the San Joaquin River from entering Old River, which would expose them to SWP and CVP diversion operations and unscreened agricultural diversions.

DWR proposes to replace the existing spring HOR barrier design in 2009 with a behavioral or NPB at the Head of Old River. The NPB would test the use of bubbles, light, and sound to prevent the outmigrating smolts from entering the south Delta, rather than the current rock barrier design.

2. Regulatory Permit History

In 1991, the Corps issued a permit to DWR to install and operate the TBP from 1991 through 1995, as a test program for evaluating the efficacy of the proposed permanent barriers program. In 1996, DWR determined that more studies were warranted for the barrier programs and requested an additional 5-year extension to the original permit issued by the Corps. This permit extension required that DWR comply with the United States Fish and Wildlife Service (USFWS) 1996 biological opinion for delta smelt (*Hypomesus transpacificus*) and conference report for splittail (*Pogonichthys macrolepidotus*). Additionally, the California Department of Fish and Game (CDFG) issued a biological opinion for state listed species in 1996 (revised in 1997) which addressed Sacramento River winter-run Chinook salmon and Swainson's Hawk (*Buteo swainsoni*). In November, 2000, DWR submitted a 404 permit application for the TBP program to the Corps. DWR requested that the duration of the program continue through December 31, 2007. The USFWS issued a new biological opinion for the TBP on March 30, 2001, followed by the issuance of a biological opinion by NMFS on April 5, 2001. The Corps issued a 404 permit for the TBP on April 11, 2001, that expired on December 31, 2007. In late 2006 and early 2007, DWR and NMFS staff discussed the need to reinitiate section 7 consultation to include TBP effects upon the newly listed Southern DPS of green sturgeon as well as the recently designated critical habitat for Central Valley spring-run Chinook salmon and Central Valley steelhead. In addition, staff discussed extending the current TBP operations another 3 years until December 31, 2010. On May 5, 2008, NMFS issued a new biological opinion for the South Delta TBPfor the continuation of the action through implementation year 2010.

B. Project Facilities

1. Construction of the Barriers

The TBP entails the placement of rock barriers within the channels of ORT (37.8100 N, -121.5427 W), MR (37.8856 N, -121.4799 W), GLC (37.8198 N; -121.4477 W), and Old River near Mossdale (HOR; 37.8082 N, -121.3287 W). Quarry rock is stockpiled alongside the sections of river adjacent to the barrier installation sites on the waterside of the levee crown. Each spring, heavy construction equipment is mobilized to move the stockpiled rock from its storage location adjacent to the river channel and into the channel to form the barriers. Large front loaders, dump trucks, and long-reach excavators are used to move and place the materials. Typically, machinery works from both banks of the channel to place the rock material, as well as any additional materials such as culverts, flashboard structures, concrete reinforcing mats, or other structures. Depending on the individual design of each barrier, the 48-inch diameter steel pipes used as culverts are placed by crane after the bed of the barrier is constructed. If the barrier abutments remain in place over the winter, the culverts are typically left in place also. As the rock barrier is extended into the channel, machinery can utilize the crown of the barrier to move farther into the channel on top of the barrier to place additional materials. Construction typically takes 1-2 weeks to complete for each barrier. Removal of the barriers occurs in the fall and the installation procedure is reversed.

2. Physical Description of the Temporary Barriers

a. *Head of Old River Barrier*

This barrier is at the divergence of Old River from the San Joaquin River near the City of Lathrop. The spring HOR barrier was originally designed to withstand San Joaquin River flows of about 3,000 cubic feet per second (cfs). However, through the years, an alternate design was developed to include flows higher than the benchmark 3,000 cfs. A "low flow" barrier would be built to an elevation of +10 feet mean sea level (MSL) when the target flows during the Vernalis Adaptive Management Plan (VAMP) are below 7,000 cfs. A "high flow" barrier would be built to an elevation of +11 feet MSL for San Joaquin River target flows above 7,000 cfs and additional rock material would be placed on the abutments to raise their elevations to +13 feet MSL. Both designs are equipped with six 48-inch operable culverts with slide gates which are placed adjacent to the south abutment of the barrier, parallel to the flow of water in the Old River channel. The gates can be operated to allow differential amounts of San Joaquin River water to flow into Old River to facilitate the maintenance of water elevations in the South Delta channels during the spring VAMP actions. These operable culverts were added in response to complaints from farmers in the SDWA that the installation of the HOR barrier negatively impacts the water elevations in the South Delta. The steel frames of the slide gates on the culverts also enable fyke nets to be attached to the culverts to monitor fish entrainment through them during the spring installation. The barrier is approximately 225 feet long, 85 feet wide at the base of the barrier, and is composed of approximately 12,500 tons of quarry rock. The middle section of the barrier has been backfilled with clay and armored with concrete mats to protect it against scouring during overtopping flows. The barriers are installed when ambient flows in the San Joaquin River are below 5,000 cfs. The installation process can not be carried out when flows exceed 5,000 cfs.

The fall HOR barrier is similar in design to the spring HOR barrier, except that the fall barrier is smaller in size than its spring counterpart. It will be constructed with six 48-inch operable culverts and is approximately 225 feet long, 55 feet wide at the base of the barrier, has a crest elevation of +8 feet MSL, and is composed of approximately 7,500 tons of quarry rock. In addition, a small 30-foot wide weir is constructed in the barrier's middle section with a crest elevation of 0.0 feet MSL. This notch is designed to facilitate upstream movement of adult salmon that may move through the Old River system of channels back into the mainstem of the San Joaquin River.

b. *Old River near Tracy Barrier*

The ORT barrier is located near the CVP's Tracy fish screen facility on Old River, approximately 0.5 miles east of the CVP's inlet. The barrier is constructed with approximately 2,500 cubic yards of quarry rock, measuring approximately 250 feet long, and 60 feet wide at its base. The center of the barrier has a 75-foot wide weir that is constructed to an elevation of +2.0 feet MSL. Beneath the center portion of the weir, the ORT contains nine 48-inch culverts, each 56 feet long and placed 2 feet apart, with tidally activated flap gates on the upstream end of the culvert. The inverts of the culverts are installed at an elevation of -6.0 feet MSL. The structure allows tidal flows to enter the channel upstream of the barrier by overtopping the weir crest or flowing through the submerged culverts. The tidal flow is then partially retained during the ebb tide by the barrier elevation and the closure of the tidal flap gates on the upstream side of the culvert. This will allow agricultural pumps to operate throughout each tidal cycle by maintaining an average water elevation of at least +1 foot MSL on the low tides.

The ORT barrier will be constructed with boat portage facilities that consist of two boat launching ramps and a staffed vehicle that can tow a universal boat trailer. The boat launching ramps are constructed along the north bank of Old River, allowing boater access and portage on the upstream and downstream sides of the barrier. The ramps are constructed with concrete matting with an adjacent encapsulated floating dock system for temporary boat mooring while awaiting portage around the barrier.

c. *Middle River Barrier*

The MR barrier is a rock barrier constructed with a lowered center weir section. It consists of approximately 2,300 cubic yards of rock and sand placed across Middle River near its confluence with Victoria and North Canals. The MR barrier will have six 48-inch culverts installed with a bottom invert of -6.0 feet MSL. Three culverts will be placed on each of the north and south abutments of the barrier. Each culvert will have a tidally activated flap-gate on its upstream end. The main portion of the MR barrier will be approximately 270 feet long and 50 wide at the base. The center portion of the barrier will consist of a 140-foot wide weir with a crest elevation of +1 foot MSL. The structure allows tidal flows to enter the channel upstream of the barrier by overtopping the weir crest or flowing through the submerged culverts. The tidal flow is then partially retained during the ebb tide by the barrier elevation and the closure of the tidal flap gates on the culvert. This will allow agricultural pumps to operate throughout each tidal cycle by maintaining an average water elevation of at least +1 foot MSL on the low tides. The MR barrier also has an unmanned boat portage consisting of a gravel boat ramp on each side of the southern abutment. The ramps can be used to carry or drag a small boat across the barrier and launch it on the opposite side of the barrier. The MR barrier abutments will remain in place throughout the year, while the center sections will be removed during the non-irrigation season (December through March). The tide gates will be tied open when the center section is removed.

d. *Grant Line Canal Barrier*

The GLC barrier is constructed with approximately 12,600 tons of rock. It is approximately 300 feet long and 50 feet wide at the base. The elevation of the barrier abutments will be +2 feet MSL. The barrier also includes six 48-inch diameter culverts with tidally operated flap gates on the upstream end of the culverts to permit tidal flow to enter the channel upstream and be retained as the tide ebbs. The flap gates can be tied open if required, or when the HOR barrier is concurrently operating to maintain the required hydrologic conditions. The culverts are installed under the abutment on the south side of the canal, allowing the abutment to remain in place throughout the year. The center portion of the barrier consists of a 140-foot wide weir, with a crest elevation of +1.0 foot MSL. In 2002, a small additional weir was constructed adjacent to the culverts on the southern abutment to provide passage for delta smelt. It has guides to install flash boards if it becomes necessary to manage water elevations at the barrier. In addition, a small boat portage facility, similar to the one at the ORT barrier, is constructed on the north side of the channel

3. Barrier Operation Schedule

a. *HOR Barrier*

The spring HOR barrier will not be fully closed or operated prior to April 15. The barrier will be completely removed by May 15, unless the fishery agencies (CDFG, USFWS, NMFS) request it remain operating until May 31. Initiation of installation and operation of the fall HOR barrier is at the discretion of the CDFG. Installation is usually triggered by low flows in the San Joaquin River and depressed DO in the Port of Stockton and Stockton Ship Channel between Channel Point and Turner Cut. Historically, the fall barrier has been operated from mid-September through the end of November. Regardless of its installation date, the fall HOR barrier will be completely removed no later than November 30, and frequently is removed earlier in November. In addition, the fall barrier is constructed with a notch to facilitate the upstream passage of adult Chinook salmon or steelhead from Old River. This notch is to remain open as long as the fall HOR barrier is in place (see Appendix A: Table 1).

b. *ORT Barrier*

This barrier will not be fully closed or operated prior to April 15. If the HOR barrier is not installed, or is installed and then removed prior to May 31, the ORT barrier flap gates will be secured in an open position until June 1. The barrier will be breached by October 31 and completely removed by November 7. However, if the fall HOR barrier is installed, the ORT barrier may remain operating through November and will be completely removed by November 30. By September 15, the ORT barrier will have a notch cut into its crest and left in place until the barrier is removed. This notch will act as a weir to allow for the passage of adult Chinook salmon and steelhead migrating up the Old River channel.

c. *MR Barrier*

This barrier will not be fully closed or operated prior to April 15. If the HOR barrier is not installed, or is installed and then removed prior to May 31, the MR barrier flap gates will be secured in an open position until June 1. The barrier will be breached by October 31 and completely removed by November 7. However, if the fall HOR barrier is installed, the Middle River barrier may remain operating through November and will be completely removed by November 30. By September 15, the MR barrier will have a notch created in its crest and left in place until the barrier is removed. This notch will act as a weir to allow for the passage of adult Chinook salmon and steelhead migrating up the Old River channel.

d. *Grant Line Canal Barrier*

Provided that the spring HOR barrier is installed for that year, the GLC barrier will not be fully closed or operated until April 15. During the April 15 through May 31 period, the GLC barrier flap gates will be secured in an open position, the weir section will be constructed to a reduced height of +0.5 feet MSL, and a flash board structure will be installed on the south embankment to allow for passage of delta smelt. If the spring HOR barrier is not installed, then construction on the GLC barrier will not begin until May 15, and will not be fully closed and operated until June 1. The elevation of the GLC barrier weir height will remain at +0.5 feet MSL until June 15, when it may be raised to the normal operational elevation of +1.0 feet MSL. The flash board structure will also operate continuously until June 15. The barrier will be breached by October 31 and completely removed by November 7. However, if the fall HOR barrier is installed, then the GLC barrier may remain in operation through November and completely removed by November 30. By September 15, the GLC barrier will have a notch created and left in place until the barrier is removed, to allow for passage of adult migrating salmon.

In the event that the spring HOR barrier cannot be installed due to high flows in the San Joaquin River in excess of 5,000 cfs, the GLC barrier may be installed in conjunction with the MR and ORT barriers to create a hydraulic barrier. Under this operational scenario, the barrier will not be fully closed or operated until April 15. Installation for the purposes of a hydraulic barrier is at the discretion of the fishery agencies, which will receive at least 2 weeks advance notice of the anticipated installation by DWR.

4. Spring Barrier Operation Agreement with USFWS

During the previous 2001 section 7 consultation process, the following spring operational agreement between DWR and USFWS was developed and has been incorporated into the proposed operation schedule for the TBP since then:

a. The MR barrier may be installed as early as March 1 at the discretion of the USFWS. Such early installation will depend upon the rate of export at the CVP and SWP as well as the most recent scientific data available on delta smelt that shows successful adult migration and spawning. In the absence of an early installation of the MR barrier at USFWS' discretion, the MR barrier may begin construction on April 7 and be fully operated from April 15 to May 15, provided that the HOR barrier is operated concurrently. If, during the April 15 to May 15 period, the HOR barrier is installed and subsequently removed prior to May 15, the flap gates on the MR barrier will be secured in the open position from the time that the HOR barrier is breached through May 15. If the HOR barrier is not installed during the April 15 to May 15 period, the MR barrier may begin construction on May 7 and be fully operated after May 15. Between May 15 to June 1, the flap gates on the MR barrier will only be closed if the need for full operation of the MR barrier is clearly demonstrated by DWR through forecasting water levels by Delta modeling and/or by actual stage data collected in the field (such data will be provided to the USFWS prior to closing the flap gates). The MR barrier will be completely removed by November 30 in all cases.

b. Construction on the ORT barrier may begin on April 1 and be fully operated from April 15 to May 15, provided that the HOR barrier is operated concurrently. In-water work to construct the ORT barrier will not commence before April 7. If, during the April 15 to May 15 period, the HOR barrier is installed and subsequently removed prior to May 15, the flap gates on the ORT barrier will be secured in the open position from the time that the HOR barrier is breached through May 15. If the HOR barrier is not installed during the April 15 through May 15 period, the start of ORT barrier construction may begin on May 1 and the barrier made fully operational after May 15. Between May 15 to June 1, the flap gates on the ORT barrier will only be closed if the need for full operation of the ORT barrier is clearly demonstrated by DWR through forecasting water levels by Delta modeling and/or by actual stage data collected in the field (such data will be provided to the USFWS prior to closing the flap gates). The ORT barrier will be completely removed by November 30 in all cases.

c. The northern abutment and boat ramp of the GLC barrier may begin construction on April 1 provided that the Head of Old River barrier is being constructed concurrently.

Closing of the flap gates on the south abutment and the center section of the GLC barrier may commence after April 15 if the HOR barrier is concurrently in operation and if the need for full operation of the GLC barrier is clearly demonstrated by DWR through forecasting water levels by Delta modeling and/or by actual stage data collected in the field (such data will be provided to the USFWS prior to closing the center and south sections of the barrier). If the HOR barrier is installed and subsequently removed prior to May 15 because of high flows, the flap gates on the GLC barrier will be tied in the open position from the time that the HOR barrier is breached through May 15. If the HOR barrier is installed and removed prior to May 15 because of delta smelt concerns, the GLC barrier will not be fully operated prior to May 15 or, if the GLC barrier is already installed, then the center section of the GLC barrier will be removed and the flap gates on the GLC barrier will be tied open until May 15, concurrent with the removal of the HOR barrier.

d. If the HOR barrier is not installed due to high flows, then the northern abutment and boat ramp of the GLC barrier may begin construction on May 1. Closing of the flap gates on the south abutment and the center section of the GLC barrier may commence anytime on or after May 15 providing that: (1) the need for full operation of the GLC barrier is clearly demonstrated through forecasting water levels by Delta modeling and/or by actual stage data collected in the field (such data will be provided to the USFWS prior to closing the center and south section flap gates of the barrier; and (2) the yellow light trigger for delta smelt is not in effect. If the GLC barrier is fully closed and subsequently, the yellow light trigger is tripped, the USFWS may require DWR to remove the center section of the GLC barrier and open the flap gates on the south abutment, but only after reductions in CVP/SWP exports consistent with Condition 5 below are determined by USFWS to be inadequate to protect delta smelt. In that event, the center section of the GLC barrier and the flap gates on the south abutment will not be replaced and closed, respectively, until the USFWS determines it is appropriate. It is the expectation of the USFWS that such determination would be made at or about the same time that CVP/SWP exports would be permitted to resume to normal levels. The GLC barrier will be completely removed by November 30.

e. Both prior to and after a yellow light is triggered, actions will be taken to protect and improve conditions for delta smelt and minimize entrainment at the CVP and SWP export facilities to avoid the triggering of a yellow or, subsequently, a red light condition. Such actions will include, but not be limited to: (1) reoperation of the culverts and flap gates on installed temporary barriers; (2) use of the joint point of diversion; and (3) reductions in the CVP and SWP exports. Export reductions taken as the result of recommendations by USFWS to improve conditions for delta smelt will be covered by the Environmental Water Account (EWA) and/or by Central Valley Project Improvement Act (CVPIA) b(2) water. Export reductions taken by the CVP/SWP to improve South Delta water levels in combination with changes in the operation of culverts and flap gates on installed temporary barriers will not be covered by EWA water assets.

f. In the event that the red light trigger is tripped, one of the following two actions will immediately be taken by DWR and the Bureau of Reclamation (Reclamation) to improve conditions for delta smelt:

   i. If the HOR barrier (if installed) is removed, the center section of the GLC barrier will also be removed and the flap gates on the south abutment of the GLC barrier will be tied opened. The center section of the GLC barrier and the flap gates on the south abutment will not be rebuilt and closed, respectively, until the USFWS determines it is appropriate to do so (*i.e.*, delta smelt situation has improved). It is the expectation of the USFWS that such a determination would be made at or about the same time that CVP/SWP exports would be permitted to resume to normal levels, or;

ii. SWP and CVP exports would be reduced further to levels determined by DWR and Reclamation as necessary to protect South Delta water levels. Such reductions, if made during times when the center section of the GLC barrier remains in place, would not be covered by EWA water assets.

g. In the event that the spring HOR barrier is not installed between April 15 and May 15, then the USFWS, at its discretion, may allow installation and operation of the MR, ORT and GLC barriers from April 15 through May 15 to implement the "hydraulic barrier" concept in the waterways of the South Delta.

h. The spring HOR barrier installation will begin on April 1, with in-water construction starting on April 7; however, the barrier will not be fully operated until April 15. The HOR barrier may be operated through May 15. At the discretion of the Fishery Agencies, the HOR barrier may continue operations until May 31 or be breached at any time prior to that consistent with Condition (f) above.

i. Installation of the fall HOR barrier will be at the discretion of CDFG. Any barriers operating after September 15 will be notched beginning September 15 to allow for passage of adult salmon.

j. During times of EWA expenditures or CVPIA b(2) water use directly related to CVP and/or SWP export curtailments, the tidal flap-gates on the MR, ORT and GLC barriers will be secured in the open position.

k. The California Bay-Delta Authority (CALFED) Final Programmatic Environmental Impact Report/Environmental Impact Study (EIR/EIS) recognized that additional measures may be necessary to help South Delta agricultural diverters when the HOR barrier is closed: "Construction of barriers on other South Delta channels, such as Middle River and Old River near Tracy fish facility, **or their functional equivalent** (emphasis added), may be necessary to alleviate the reduced water levels caused by the closure of the head of Old River barrier in combination with CVP and SWP exports." To pursue the possibility of providing functional equivalence, DWR will take the following actions:

i. During the time that any of the temporary barriers are installed, if any diverter within the SDWA notifies DWR that they are experiencing water level problems, DWR will notify the USFWS in writing of the diverter who is experiencing the problem and the nature and extent of the problem.

ii. If renting or installing portable pumps may alleviate the immediate problem, DWR will provide the portable pumps if feasible or reimburse the diverter for the rental costs of the portable pumps.

iii. DWR will conduct an investigation of whether it is feasible to solve the diverter's water supply problem through dredging and/or modification or relocation of the diverter's intake structure in lieu of barrier operation and submit a written report to USFWS on the conclusions of their investigation.

iv. If the investigation concludes that dredging and/or or modification or relocation of the diverter's intake structure is a feasible alternative to protect the diverter's water supply in lieu of operation of one or more of the barriers, DWR will work in earnest to obtain permits and agreements necessary to accomplish the proposed work, including any appropriate cost sharing arrangements. The work is to be accomplished at the earliest possible date. If the work involves modifying or relocating an existing diversion intake, a copy of the Memorandum of Agreement Regarding Fish Screens must be signed by the diverter prior to any work taking place. Immediately after any dredging and/or diversion extension, DWR will provide the USFWS with a report detailing the work and the amount of shallow water habitat affected by such actions. DWR will mitigate these impacts at a ratio to be determined by USFWS.

5. Proposed Installation of a Non-Physical Barrier in Place of the HOR Barrier for 2009

The NPB would be approximately 112 meters long, comprised of 14 separate 8-meter sections (Figure 2). The barrier frame would include 56 sound projectors spaced approximately 2 meters apart, 112 strobe lights consisting of LED, and perforated pipe. The LED strobe lights would be powered from an "accumulator" positioned every 12 LEDs. A mounting plate would be attached to the support tray to house the accumulators.

Each of the 8-meter sections would have adjustable height pivots to provide flexibility to lower or raise each section to follow the riverbed contour. The barrier frame would be supported by four piles driven into the bottom of the river channel.

Additionally, concrete piers would be placed to support the frame above the riverbed in several locations to make sure the system does not move out of alignment and allow for vertical adjustment of the barrier relative to the riverbed or water surface. Straining wires or other supports also may be required. In the center channel, the barrier frame would be approximately 0.3 to 0.6 meters from the channel bottom to allow passage of bottom-dwelling fish, such as green sturgeon, while providing maximum deterrence in the water column.

The air bubble curtain would be generated by passing air (approximately 950 cubic feet per minute) through a uniformly perforated pipe attached to the barrier frame. As described above, the primary function of the bubble curtain is to contain the sound generated by the sound projectors. Essentially, the sound is encapsulated within the bubble curtain, which allows a precise linear wall of sound to be developed (Bowen *et al.* 2008, see Figure 3).

Up to 30 amps of current from an inductively rated power supply (115 volts) would be required to run the complete electrical system. A small trailer would house the control units fro the NPB system, signal generators, and amplifiers. The trailer would be located on the left bank of the San Joaquin River, on a waterside berm adjacent to the location of the NPB. This site has previously been used to stockpile stones for the HOR rock barrier. The electrical generator will be housed inside the trailer. This will ensure that little noise will be heard outside of the trailer while the generator is running. The trailer will be towed to and from the waterside berm location and will not require the construction or improvements of any roads in the action area.

Installation of the NPB would begin on or after April 6, 2009, and removal would begin no later than May 31, 2009. Installation of the NPB would be completed in approximately 4 days. Activation and testing of the system will take approximately 6 days, beginning on or about April 10, 2009. Removal of the NPB and piles will take approximately 5 days. Construction and removal activity would occur 8–10 hours per day, every day per week, during daylight hours.

Construction vehicles would access the project site using existing roads on Stewart Tract, including those on the levee crown. These are the same access roads that are typically used during installation and removal of the HOR barrier. It is anticipated that the following equipment would be used during construction and installation of the NPB:

- Flatbed tractor/trailer
- Barge with spuds and tug
- Barge-mounted crane
- Vibratory hammer pile driver
- Work boat
- Diesel or LPG powered electrical generator
- Air compressor

In-water construction activities will begin no later than April 6, 2009. The pile foundation and concrete foot supports for the NPB will be installed first. Four, 12- to 16-inch diameter steel piles will be driven with a vibratory driver into the river channel bottom from a barge. It is anticipated it will take about 30 minutes to drive each pile and that all of the driving will occur in 1 day resulting in 2 hours of total pile driving time. Each pile will be driven to approximately 40 to 60 feet into the river bed. It will require approximately 1 hour between each pile driving location to reposition the barge to the next piling location, load the pile, and commence pile driving activities.

Following the installation of the piles, the concrete piers will be positioned with the barge-mounted crane. Each pier is approximately 2 feet by 2 feet square by 12 feet deep. The NPB frame sections would then be lowered into the water with the crane. Divers will attach the piles and concrete piers, and then attach the air lines and power cords to the NPB.

Because the San Joaquin River transports a large debris load, which includes trees, a floating debris boom will be installed in a horseshoe configuration upstream of the NPB to trap debris just below the water surface. The debris boom will be approximately 244 meters long and will be attached to the San Joaquin River bank. Navigational buoys and lights will also be installed to ensure boater safety.

The NPB will be operated from approximately April 15 through May 15, 2009, to correspond to the timing of the VAMP experiment. During the fish releases planned for the VAMP experiment, the NPB will cycle on/off over 24-hour periods to test the effectiveness of the NPB in guiding salmon smolts away from Old River. Should the VAMP experiment be extended until the end of May, as it sometimes has in the past, the NPB would remain in operation until the VAMP experiment is completed.

6. Proposed Fisheries Monitoring Plan for the 2009 Non-Physical Barrier Experiment

One of the major objectives of the NPB experiment is to determine its effectiveness in blocking Chinook salmon migration into the channel of Old River in the south Delta. In order to measure this effectiveness, DWR, in coordination with Reclamation, will implement a monitoring program as described below.

The monitoring program will be coordinated with the VAMP experiments being implemented at the same time in the action area. The VAMP study will utilize acoustic transmitters inserted into approximately 950 Chinook salmon juveniles. These fish will be released in several groups at different times upstream of the Head of Old River. The VAMP study will install, with DWR/Reclamation assistance, fixed station receivers at three locations (see Appendix B: Figure 1b):

- San Joaquin River-Upstream of bifurcation and fish barrier (SJU),
- San Joaquin River-Downstream of bifurcation point (SJD), and
- Old River-Downstream of bifurcation point (ORD).

A critical assumption is that the VAMP team, with DWR/Reclamation assistance, can deploy HTI [Hydroacoustic Technology, Inc. (http://www.htisonar.com/index.htm)] acoustic receivers in such a manner as to determine the fate of fish passing through the study area (see Appendix B: Figure 1b). If a fish moves past the SJU receiver (*e.g.*, enters the experimental area), then it can either disappear or die upstream of the NPB without detection at the downstream receivers, pass the downstream receiver at the SJD location (deterred from entering Old River), or pass through the barrier and subsequently detected at the ORD receiver location (undeterred).

Then deterrence efficiency may be calculated as: $E = D/ (D+U)$ where,

E = deterrence efficiency,
D = number of fish passing SJD, and
U = undeterred fish passing ORD.

The denominator includes all fish making a decision and passing SJD or ORD. Fish that do not pass SJD or ORD could have been eaten by a predator before encountering the NPB. In addition to determining deterrence efficiency, a DIDSON camera will be deployed by DWR immediately upstream of the NPB. DWR will operate and record DIDSON images throughout a 48-hr period beginning with each VAMP release. This will allow the capture of the behavior of a large number of experimental release fish that reach the NPB.

In addition, DWR will employ mobile acoustic receivers to track Chinook salmon juveniles in the vicinity of the barrier. Fish will be tracked continuously upstream of the NPB and while entering the experimental area. DWR will monitor 10 individual fish in this fashion to obtain information regarding the variability in fish movement through the area. DWR will produce a Technical Memorandum by June 30, 2009 describing the behavior of the fish in the vicinity of the barrier. Additionally, DWR will acquire fixed acoustic receiver data and estimate the effectiveness of the barrier using the above equation.

C. Action Area of the South Delta Temporary Barriers Project

The action area is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR § 402.02). The action area, for the purposes of this biological opinion includes the southern Sacramento-San Joaquin Delta and generally comprises the lands and waterways of the Delta southwest of the City of Stockton. Major waterways within the South Delta include the San Joaquin River, Old River, Middle River, Woodward and North Victoria Canals, Grant Line and Fabian Canals, Italian Slough, Tom Paine Slough and the adjoining canals of the CVP and SWP. However, due to anticipated indirect and interrelated affects of the TBP, the action area for this consultation not only encompasses the lands and waterways described above but includes lands and waterways of the central Delta including the lower San Joaquin downstream of Old River, Columbia Cut and Turner Cut, and all reaches of Middle River and Old River and adjoining sloughs and canals.

III. STATUS OF THE SPECIES AND CRITICAL HABITAT

The following Federally listed species evolutionarily significant units (ESU) or distinct population segments (DPS) and proposed and designated critical habitat occur in the action area and may be affected by the proposed TBP:

Sacramento River winter-run Chinook salmon ESU (*Oncorhynchus tshawytscha*)
Listed as endangered (June 28, 2005, 70 FR 37160)

Central Valley spring-run Chinook salmon ESU (*Oncorhynchus tshawytscha*)
Listed as threatened (June 28, 2005, 70 FR 37160)

Central Valley steelhead DPS (*Oncorhynchus mykiss*) Listed as threatened (January 5, 2006, 71 FR 834)

Central Valley steelhead designated critical habitat
(September 2, 2005, 70 FR 52488)

Southern DPS of North American green sturgeon (*Acipenser medirostris*)
Listed as threatened (April 7, 2006, 71 FR 17386)

Southern DPS of North American green sturgeon proposed critical habitat
(September 8, 2008, 73 FR 52084)

A. Species and Critical Habitat Listing Status

NMFS has recently completed an updated status review of 16 salmon ESUs, including Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and concluded that the species' status should remain as previously listed (June 28, 2005, 70 FR

37160). On January 5, 2006, NMFS published a final listing determination for 10 steelhead DPSs, including Central Valley steelhead. The new listing concludes that Central Valley steelhead will remain listed as threatened (71 FR 834).

Sacramento River winter-run Chinook salmon were originally listed as threatened in August 1989, under emergency provisions of the Endangered Species Act of 1973, as amended (ESA), and formally listed as threatened in November 1990 (55 FR 46515). The ESU consists of only one population that is confined to the upper Sacramento River in California's Central Valley. The Livingston Stone National Fish Hatchery (LSNFH) population has been included in the listed Sacramento River winter-run Chinook salmon population as of June 28, 2005 (70 FR 37160). NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). The ESU was reclassified as endangered on January 4, 1994 (59 FR 440), due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. Critical habitat was delineated as the Sacramento River from Keswick Dam at river mile (RM) 302 to Chipps Island (RM 0) at the westward margin of the Sacramento-San Joaquin Delta (Delta), including Kimball Island, Winter Island, and Brown's Island; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge. Critical habitat for Sacramento River winter-run Chinook salmon does not occur within the action area.

Central Valley spring-run Chinook salmon were listed as threatened on September 16, 1999 (64 FR 50394). This ESU consists of spring-run Chinook salmon occurring in the Sacramento River basin. The Feather River Hatchery (FRH) spring-run Chinook salmon population has been included as part of the Central Valley spring-run Chinook salmon ESU in the most recent modification of the Central Valley spring-run Chinook salmon listing status (June 28, 2005, 70 FR 37160). Critical habitat was designated for Central Valley spring-run Chinook salmon on September 2, 2005 (70 FR 52488), but does not occur in the action area for the proposed TBP.

Central Valley steelhead were listed as threatened under the ESA on March 19, 1998 (63 FR 13347). This DPS consists of steelhead populations in the Sacramento and San Joaquin River (inclusive of and downstream of the Merced River) basins in California's Central Valley. The Coleman National Fish Hatchery and FRH steelhead populations have been included as part of the Central Valley steelhead DPS in the most recent modification of the Central Valley steelhead listing status (January 5, 2006, 71 FR 834). These populations were previously included in the DPS but were not deemed essential for conservation and thus not part of the listed steelhead population. Critical habitat was designated for steelhead in the Central Valley on September 2, 2005 (70 FR 52488). Critical habitat includes the stream channels to the ordinary high water line within designated stream reaches such as those of the American, Feather, and Yuba Rivers, and Deer, Mill, Battle, Antelope, and Clear Creeks in the Sacramento River basin; the Calaveras, Mokelumne, Stanislaus, and Tuolumne Rivers in the San Joaquin River basin; and, the Sacramento and San Joaquin Rivers and Delta. Designated critical habitat for the Central Valley steelhead is found within the action area.

The Southern DPS of North American green sturgeon was listed as threatened on April 7, 2006 (71 FR 17757). The Southern DPS presently contains only a single spawning population in the Sacramento River, and rearing individuals may occur within the action area. No critical habitat has been designated or proposed for the Southern DPS of North American green sturgeon.

B. Species Life History and Population Dynamics

1. Chinook Salmon

a. *General Life History*

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). "Stream-type" Chinook salmon, enter freshwater months before spawning and reside in freshwater for a year or more following emergence, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Spring-run Chinook salmon exhibit a stream-type life history. Adults enter freshwater in the spring, hold over summer, spawn in fall, and the juveniles typically spend a year or more in freshwater before emigrating. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over summering by adults and/or juveniles.

Chinook salmon typically mature between 2 and 6 years of age (Myers *et al.* 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and the actual time of spawning (Myers *et al.* 1998). Both spring-run and winter-run Chinook salmon tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. For comparison, fall-run Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require streamflows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate streamflows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38 °F to 56 °F (Bell 1991, CDFG 1998). Boles (1988) recommends water temperatures below 65 °F for adult Chinook salmon migration, and Lindley *et al.* (2004) report that adult migration is blocked when temperatures reach 70 °F, and that fish can become stressed as temperatures approach 70 °F. Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60 °F; although salmon can tolerate temperatures up to 65 °F before they experience an increased susceptibility to disease.

Information on the migration rates of Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin where information regarding migration behavior is needed to assess the effects of dams on travel times and passage (Matter *et al.* 2003). Keefer *et al.* (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter *et al.* (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River. Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower

Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion while migrating upstream over the course of several days at a time (CALFED 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). Adults are thought to exhibit crepuscular behavior during their upstream migrations; meaning that they primarily are active during twilight hours. Recent hydroacoustic monitoring showed peak upstream movement of adult Central Valley spring-run Chinook salmon in lower Mill Creek, a tributary to the Sacramento River, occurring in the 4-hour period before sunrise and again after sunset.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995a). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. The upper preferred water temperature for spawning Chinook salmon is 55 °F to 57 °F (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001).

Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87 percent of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41 °F to 56 °F (44 °F to 54 °F [Rich 1997], 46 °F to 56 °F [NMFS 1997 Winter Run Chinook salmon Recovery Plan], and 41 °F to 55.4 °F [Moyle 2002]). A significant reduction in egg viability occurs at water temperatures above 57.5 °F and total embryo mortality can occur at temperatures above 62 °F (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61 °F and 37 °F, respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the alevins (yolk-sac fry) remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and other micro-crustaceans. As they switch from endogenous nourishment to exogenous feeding, the fry's yolk-sac is reabsorbed, and the belly suture closes over the former location of the yolk-sac (button-up fry). Fry typically range from 25 mm to 40 mm during this stage. Some fry may take up residence in their natal stream for several weeks to a year or more, while others are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991).

Fry then seek nearshore habitats containing beneficial aspects such as riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996a). The benefits of shallow water habitats for salmonid rearing also have recently been realized as shallow water habitat has been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001).

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams may spur outmigration of juveniles when they have reached the appropriate stage of maturation (Kjelson *et al.* 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is crepuscular. Documents and data provided to NMFS in support of ESA section 10 research permit applications depicts that the daily migration of juveniles passing Red Bluff Diversion Dam (RBDD) is highest in the four hour period prior to sunrise (Martin *et al.* 2001). Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al.* (1982) found fry Chinook salmon to travel as fast as 30 km per day in the Sacramento River and Sommer *et al.* (2001) found rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (Healey 1980, Levy and Northcote 1981).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries. In addition, Central Valley spring-run Chinook salmon juveniles have been observed rearing in the lower reaches of non-natal tributaries and intermittent streams in the Sacramento Valley during the winter months (Maslin *et al.* 1997, Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1982, Sommer *et al.* 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54 °F to 57 °F (Brett 1952). In Suisun and San Pablo Bays water temperatures reach 54 °F by February in a typical year. Other portions of the Delta (*i.e.*, South Delta and Central Delta) can reach 70 °F by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1982, Levings 1982, Levings *et al.* 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle *et al.* (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson *et al.* (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicates that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (*i.e.*, fall-run Chinook salmon) MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

b. *Sacramento River Winter-run Chinook salmon*

The distribution of winter-run Chinook salmon spawning and rearing historically was limited to the upper Sacramento River and its tributaries, where spring-fed streams provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Slater 1963, Yoshiyama *et al.* 1998). The headwaters of the McCloud, Pit, and Little Sacramento Rivers, and Hat and Battle Creeks, historically provided clean, loose gravel; cold, well-oxygenated water; and optimal stream flow in riffle habitats for spawning and incubation. These areas also provided the cold, productive waters necessary for egg and fry development and survival, and juvenile rearing over the summer. The construction of Shasta Dam in 1943 blocked access to all of these waters except Battle Creek, which has its own impediments to upstream migration (*i.e.*, the fish weir at the Coleman National Fish Hatchery and other small hydroelectric facilities situated upstream of the weir) (Moyle *et al.* 1989, NMFS 1997, 1998a,b). Approximately, 299 miles of tributary spawning habitat in the upper Sacramento River is now inaccessible to winter-run Chinook salmon. Yoshiyama *et al.* (2001) estimated that in 1938, the Upper Sacramento had a "potential spawning capacity" of 14,303 redds. Most components of the winter-run Chinook salmon life history (*e.g.*, spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River.

Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher 1985) and migrate past the RBDD from mid-December through early August (NMFS 1997). The majority of the run passes RBDD from January through May, with the peak passage occurring in mid-March (Hallock and Fisher 1985). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type (see Table 2 in text; Yoshiyama *et al.* 1998, Moyle 2002). Spawning occurs primarily from mid-April to mid-August, with the peak activity occurring in May and June in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991). The majority of Sacramento River winter-run Chinook salmon spawners are 3 years old.

Table 2. The temporal occurrence of adult (a) and juvenile (b) Sacramento River winter-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

a) Adult migration

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sac. River basin[a]	■	■	■	■	■	■	■					■
Sac. River[b]	■	■	■	■	■	■					■	■

b) Juvenile migration

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sac. River @ Red Bluff[c]	▒	▒	▒				▒■	■	■	■	■	■
Sac. River @ Red Bluff[b]	▒	▒	▒				▒	■	■	■	■	■
Sac. River @ KL.[d]	■	■	■	▒	▒			▒	▒	▒	■	■
Lower Sac. River (seine)e	■	■	■	▒	▒					▒	■	■
West Sac. River (trawl)e	■	■	■	■	▒						▒	■

KL = Knights Landing

Relative Abundance: ■ = High ■ = Medium ▒ = Low

Sources: [a]Yoshiyama *et al.* (1998); Moyle (2002); [b]Myers *et al.* (1998) ; Vogel and Marine(1991); [c]Martin *et al.* (2001); [d]Snider and Titus (2000); [e]USFWS (2001, 2001a)

Sacramento River winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994). Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin as early as mid July, typically peaks in September, and can continue through March in dry years (Vogel and Marine 1991, NMFS 1997). Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (RM 57; USFWS 2001a,b). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 millimeters (mm) and are from 5 to 10 months of age, and then begin emigrating to the ocean as early as November and continue through May (Fisher 1994, Myers *et al.* 1998).

Historical Sacramento River winter-run Chinook salmon population estimates, which included males and females, were as high as near 100,000 fish in the 1960s, but declined to under 200 fish in the 1990s (Good *et al.* 2005). Population estimates in 2003 (8,218), 2004 (7,701), 2005 (15,730) and 2006 (17,205) show a recent increase in the population size (CDFG GrandTab, February 2007) and a 3-year average of 11,259 (see Table 3 in text and Appendix B Figure 4). The 2006 run was the highest since the 1994 listing. Overall, abundance measures over the last decade suggest that the abundance is increasing (Good *et al.* 2005). However, escapement estimates for 2007 and 2008 show a precipitous decline in escapement numbers based on redd counts and carcass counts. Early estimates place the adult escapement numbers for 2007 at 2,488 fish and 2008 at 2,850 fish (CDFG Grand Tab 2009).

Table 3. Winter-run Chinook salmon population estimates from RBDD counts (1986 to 2001) and carcass counts (2001 to 2006), and corresponding cohort replacement rates for the years since 1986 (CDFG 2004a, CDFG Grand Tab February 2007).

Year	Population Estimate[a]	5-Year Moving Average of Population Estimate	Cohort Replacement Rate	5-Year Moving Average of Cohort Replacement Rate	NMFS-Calculated Juvenile Production Estimate (JPE)[b]
1986	2,596	-	-	-	
1987	2,186	-	-	-	
1988	2,885	-	-	-	
1989	696	-	0.27	-	
1990	433	1,759	0.20	-	
1991	211	1,282	0.07	-	40,100
1992	1,240	1,092	1.78	-	273,100
1993	387	593	0.90	0.64	90,500
1994	186	491	0.88	0.77	74,500
1995	1,297	664	1.05	0.94	338,107
1996	1,337	889	3.45	1.61	165,069
1997	880	817	4.73	2.20	138,316
1998	3,002	1,340	2.31	2.48	454,792
1999	3,288	1,961	2.46	2.80	289,724
2000	1,352	1,972	1.54	2.90	370,221
2001	8,224	3,349	2.74	2.76	1,864,802
2002	7,441	4,661	2.26	2.22	2,136,747
2003	8,218	5,705	6.08	3.02	1,896,649
2004	7,701	6,587	0.94	2.71	881,719
2005	15,730	9,463	2.11	2.83	3,556,995
2006	17,205	11,259	2.09	2.70	3,890,534
2007	2,488	10,268	0.32	2.31	1,100,067
2008	2,850[c]	9,195	0.18	1.13	1,152,043[d]
median	**2,186**	**1,759**	**1.94**	**2.59**	**354,164**

[a]JPE estimates were derived from NMFS calculations utilizing RBDD winter-run counts through 2001, and carcass counts thereafter for deriving adult escapement numbers.

Two current methods are utilized to estimate the juvenile production of Sacramento River winter-run Chinook salmon: the Juvenile Production Estimate (JPE) method, and the Juvenile Production Index (JPI) method (Gaines and Poytress 2004). Gaines and Poytress (2004) estimated the juvenile population of Sacramento River winter-run Chinook salmon exiting the upper Sacramento River at RBDD to be 3,707,916 juveniles per year using the JPI method between the years 1995 and 2003 (excluding 2000 and 2001). Using the JPE method, they estimated an average of 3,857,036 juveniles exiting the upper Sacramento River at RBDD between the years of 1996 and 2003. Averaging these two estimates yields an estimated population size of 3,782,476.

Based on the RBDD counts, the population has been growing rapidly since the 1990s with positive short-term trends (excluding the 2007 preliminary escapement numbers). An age-structured density-independent model of spawning escapement by Botsford and Brittnacker (1998 as referenced in Good *et al.* 2005) assessing the viability of Sacramento River winter-run

Chinook salmon found the species was certain to fall below the quasi-extinction threshold of 3 consecutive spawning runs with fewer than 50 females (Good *et al.* 2005). Lindley *et al.* (2003) assessed the viability of the population using a Bayesian model based on spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures found a biologically significant expected quasi-extinction probability of 28 percent. Although the status of the Sacramento River winter-run Chinook salmon population is improving, there is only one population, and it depends on cold-water releases from Shasta Dam, which could be vulnerable to a prolonged drought (Good *et al.* 2005).

Recently, Lindley *et al.* (2007) determined that the Sacramento River winter-run Chinook salmon population that spawns below Keswick Dam is at a moderate extinction risk according to population viability analysis (PVA), and at a low risk according to other criteria (*i.e.*, population size, population decline, and the risk of wide ranging catastrophe). However, concerns of genetic introgression with hatchery populations are increasing. Hatchery-origin winter-run Chinook salmon from LSNFH have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. If this proportion of hatchery origin fish from the LSNFH exceeds 15 percent in 2006-2007, Lindley *et al.* (2007) recommends reclassifying the winter-run Chinook population extinction risk as moderate, rather than low, based on the impacts of the hatchery fish over multiple generations of spawners.

Lindley *et al.* (2007) also states that the winter-run Chinook salmon population fails the "representation and redundancy rule" because it has only one population, and that population spawns outside of the ecoregion in which it evolved. In order to satisfy the "representation and redundancy rule," at least two populations of winter-run Chinook salmon would have to be re-established in the basalt- and porous-lava region of its origin. An ESU represented by only one spawning population at moderate risk of extinction is at a high risk of extinction over an extended period of time (Lindley *et al.* 2007).

Viable Salmonid Population Summary for Sacramento River Winter-run Chinook Salmon

Abundance. Redd and carcass surveys, and fish counts, suggest that the abundance of winter-run Chinook salmon has been increasing. The depressed 2007 and 2008 abundance estimate are an exception to this trend and may represent a new cycle of poor ocean productivity (Lindley *et al.* 2009). Population growth is estimated to be positive in the short-term trend at 0.26; however, the long-term trend is negative, averaging -0.14. Recent winter-run Chinook salmon abundance represents only 3 percent of the maximum post-1967, 5-year geometric mean, and is not yet well established (Good *et al.* 2005).

Productivity. ESU productivity has been positive over the short term, and adult escapement and juvenile production have been increasing annually (Good *et al.* 2005), except for 2007 and 2008. The long-term trend for the ESU remains negative, however, as it consists of only one population that is subject to possible impacts from environmental and artificial conditions. The most recent cohort replacement rate (CRR) estimate suggests a reduction in productivity for the 1998-2001 cohorts.

Spatial Structure. The greatest risk factor for winter-run Chinook salmon lies with their spatial structure (Good *et al.* 2005). The remnant population cannot access historical winter-run Chinook salmon habitat and must be artificially maintained in the Sacramento River by a regulated, finite cold-water pool from Shasta Dam. Winter-run Chinook salmon require cold water temperatures in summer that simulate their upper basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment. Battle Creek remains the most feasible opportunity for the ESU to expand its spatial structure, which currently is limited to the upper 25-mile reach of the mainstem Sacramento River below Keswick Dam.

Diversity. The second highest risk factor for the Sacramento River winter-run Chinook salmon ESU has been the detrimental effects on its diversity. The present winter-run Chinook salmon population has resulted from the introgression of several stocks that occurred when Shasta Dam blocked access to the upper watershed. A second genetic bottleneck occurred with the construction of Keswick Dam; and there may have been several others within the recent past (Good *et al.* 2005). Concerns of genetic introgression with hatchery populations are also increasing. Hatchery-origin winter-run Chinook salmon from LSNFH have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run.

c. *Central Valley Spring-Run Chinook salmon*

Historically the spring-run Chinook salmon were the second most abundant salmon run in the Central Valley (CDFG 1998). These fish occupied the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit Rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1874, Rutter 1904, Clark 1929). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). Before the construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River alone (Fry 1961). Construction of other low elevation dams in the foothills of the Sierras on the American, Mokelumne, Stanislaus, Tuolumne, and Merced Rivers extirpated Central Valley spring-run Chinook salmon from these watersheds. Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998).

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998) and enter the Sacramento River between March and September, primarily in May and June (see Table 4 in text; Yoshiyama *et al.* 1998, Moyle 2002). Lindley *et al.* (2007) indicates adult Central Valley spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid April and mid June. Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama *et al.* 1998).

Spring-run Chinook salmon spawning occurs between September and October depending on water temperatures. Between 56 and 87 percent of adult spring-run Chinook salmon that enter the Sacramento River basin to spawn are 3 years old (Calkins *et al.* 1940, Fisher 1994).

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and the emigration timing is highly variable, as they may migrate downstream as young-of-the-year (YOY) or as juveniles or yearlings. The modal size of fry migrants at approximately 40 mm between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2007). Studies in Butte Creek (Ward *et al.* 2002, 2003, McReynolds *et al.* 2005) found the majority of Central Valley spring-run Chinook salmon migrants to be fry occurring primarily during December, January, and February; and that these movements appeared to be influenced by flow. Small numbers of Central Valley spring-run Chinook salmon remained in Butte Creek to rear and migrated as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer Creek juveniles typically exhibit a later YOY migration and an earlier yearling migration (Lindley *et al.* 2007).

Once juveniles emerge from the gravel they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac and transition to exogenous feeding (Moyle 2002). Many also will disperse downstream during high-flow events. As is the case in other salmonids, there is a shift in microhabitat use by juveniles to deeper faster water as they grow larger. Microhabitat use can be influenced by the presence of predators which can force fish to select areas of heavy cover and suppress foraging in open areas (Moyle 2002). The emigration period for spring-run Chinook salmon extends from November to early May, with up to 69 percent of the YOY fish outmigrating through the lower Sacramento River and Delta during this period (CDFG 1998). Peak movement of juvenile Central Valley spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and again in March and April. However, juveniles also are observed between November and the end of May (Snider and Titus 2000). Based on the available information, the emigration timing of Central Valley spring-run Chinook salmon appears highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others over summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998).

Table 4. The temporal occurrence of adult (a) and juvenile (b) Central Valley spring-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

(a) Adult migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac.River basin[a,b]												
Sac. River mainstem[c]												
Mill Creek[d]												
Deer Creek[d]												
Butte Creek[d]												
(b) Adult Holding												
(c) Adult Spawning												
(d) Juvenile migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sac. River Tribs[e]												
Upper Butte Creek[f]												
Mill, Deer, Butte Creeks[d]												
Sac. River at RBDD[c]												
Sac. River at KL[g]												

Relative Abundance: = High = Medium = Low

Note: Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Young of the year spring-run Chinook salmon emigrate during the first spring after they hatch.

Sources: [a]Yoshiyama *et al.* (1998); [b]Moyle (2002); [c]Myers *et al.* (1998); [d]Lindley *et al.* (2007); CDFG (1998); [f]McReynolds *et al.* (2005); Ward *et al.* (2002, 2003); [g]Snider and Titus (2000)

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the FRH. In 2002, the FRH reported 4,189 returning spring-run Chinook salmon, which is 22 percent below the 10-year average of 4,727 fish. However, coded-wire tag (CWT) information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices. Because Chinook salmon have not always been temporally separated in the hatchery, spring-run and fall-run Chinook salmon have been spawned together, thus compromising the genetic integrity of the spring-run Chinook salmon stock. The number of naturally spawning spring-run Chinook salmon in the Feather River has been estimated only periodically since the 1960s, with estimates ranging from 2 fish in 1978 to 2,908 in 1964. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of spring-run and fall-run Chinook salmon (Good *et al.* 2005). For the reasons discussed above, the Feather River spring-run Chinook population numbers are not included in the following discussion of ESU abundance.

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance, ranging from 1,403 in 1993 to 24,725 in 1998 (see Table 5 in text and Appendix B Figure 5). Sacramento River tributary populations in Mill, Deer, and Butte Creeks are probably the best trend indicators for the Central Valley spring-run Chinook salmon ESU as a whole because these streams contain the primary independent populations within the ESU. Generally, these streams have shown a positive escapement trend since 1991. Escapement numbers are dominated by Butte Creek returns, which have averaged over 7,000 fish since 1995. During this same period, adult returns on Mill Creek have averaged 778 fish, and 1,463 fish on Deer Creek. Although recent trends are positive, annual abundance estimates display a high level of fluctuation, and the overall number of Central Valley spring-run Chinook salmon remains well below estimates of historic abundance. Additionally, in 2002 and 2003, mean water temperatures in Butte Creek exceeded 21°C for 10 or more days in July (reviewed by Williams 2006). These persistent high water temperatures, coupled with high fish densities, precipitated an outbreak of Columnaris Disease (*Flexibacter columnaris*) and Ichthyophthiriasis (*Ichthyophthirius multifiis*) in the adult spring-run Chinook salmon over-summering in Butte Creek. In 2002, this contributed to the pre-spawning mortality of approximately 20 to 30 percent of the adults. In 2003, approximately 65 percent of the adults succumbed, resulting in a loss of an estimated 11,231 adult spring-run Chinook salmon in Butte Creek.

Table 5. Central Valley Spring-run Chinook salmon population estimates from CDFG Grand Tab (February 2007) with corresponding cohort replacement rates for years since 1986.

Year	Sacramento River Basin Escapement Run Size[a]	FRFH Population	Tributary Populations	5-Year Moving Average of Tributary Population Estimate	Trib CRR[b]	5-Year Moving Average of Trib CRR	5-Year Moving Average of Basin Population Estimate	Basin CRR	5-Year Moving Average of Basin CRR
1986	25,696	1,433	24,263						
1987	13,888	1,213	12,675						
1988	18,933	6,833	12,100						
1989	12,163	5,078	7,085		0.29			0.47	
1990	7,683	1,893	5,790	12,383	0.46		15,673	0.55	
1991	5,927	4,303	1,624	7,855	0.13		11,719	0.31	
1992	3,044	1,497	1,547	5,629	0.22		9,550	0.25	
1993	6,075	4,672	1,403	3,490	0.24	0.27	6,978	0.79	0.48
1994	6,187	3,641	2,546	2,582	1.57	0.52	5,783	1.04	0.59
1995	15,238	5,414	9,824	3,389	6.35	1.70	7,294	5.01	1.48
1996	9,082	6,381	2,701	3,604	1.93	2.06	7,925	1.49	1.72
1997	5,086	3,653	1,433	3,581	0.56	2.13	8,334	0.82	1.83
1998	31,471	6,746	24,725	8,246	2.52	2.58	13,413	2.07	2.09
1999	9,835	3,731	6,104	8,957	2.26	2.72	14,142	1.08	2.09
2000	9,234	3,657	5,577	8,108	3.89	2.23	12,942	1.82	1.46
2001	17,698	4,135	13,563	10,280	0.55	1.96	14,665	0.56	1.27
2002	17,409	4,189	13,220	12,638	2.17	2.28	17,129	1.77	1.46
2003	17,570	8,662	8,908	9,474	1.60	2.09	14,349	1.90	1.43
2004	13,986	4,212	9,774	10,208	0.72	1.78	15,179	0.79	1.37
2005	16,117	1,771	14,346	11,962	1.09	1.22	16,556	0.93	1.19
2006	10,652	1,952	8,700	10,990	0.98	1.31	15,147	0.61	1.20
2007	10,571	2,752	7,819	9,909	0.80	1.04	13,779	0.76	1.00
Median	11,408	3,933	8,260	9692	1.03	1.58	14,246	0.98	1.38

[a] NMFS included both the escapement numbers from the Feather River Fish Hatchery (FRFH) and the Sacramento River and its tributaries in this table. Sacramento River Basin run size is the sum of the escapement numbers from the FRFH and the tributaries.

[b] Abbreviations: CRR = Cohort Replacement Rate, Trib = tributary

Lindley *et al.* (2007) indicated that the spring-run population of Chinook salmon in the Central Valley had a low risk of extinction in Butte and Deer Creek, according to their PVA model and the other population viability criteria (*i.e.*, population size, population decline, catastrophic events, and hatchery influence). The Mill Creek population of spring-run Chinook salmon is at moderate extinction risk according to the PVA model, but appears to satisfy the other viability criteria for low-risk status. However, like the winter-run Chinook salmon population, the Central Valley spring-run Chinook salmon population fails to meet the "representation and redundancy rule" since there is only one demonstrably viable population out of the three diversity groups that historically contained them. The spring-run population is only represented by the group that currently occurs in the northern Sierra Nevada. The spring-run Chinook salmon populations that formerly occurred in the basalt and porous-lava region and southern Sierra Nevada region have been extirpated. The northwestern California region contains a few ephemeral populations of spring-run Chinook salmon that are likely dependent on the Northern Sierra populations for their continued existence. Over the long term, these remaining populations are considered to be vulnerable to catastrophic events, such as volcanic eruptions from Mount Lassen or large forest fires due to the close proximity of their headwaters to each other. Drought is also considered to pose a significant threat to the viability of the spring-run Chinook salmon populations in these three watersheds due to their close proximity to each other. One large event could eliminate all three populations.

Viable Salmonid Population Summary for Central Valley Spring-run Chinook Salmon

Abundance. The Central Valley spring-run Chinook salmon ESU has experienced a trend of increasing abundance in some natural populations, most dramatically in the Butte Creek population (Good *et al.* 2005). There has been more opportunistic utilization of migration-dependent streams overall. The FRH spring-run Chinook salmon stock has been included in the ESU based on its genetic linkage to the natural population and the potential development of a conservation strategy for the hatchery program.

Productivity. The 5-year geometric mean for the extant Butte, Deer, and Mill Creek spring-run Chinook salmon populations ranges from 491 to 4,513 fish (Good *et al.* 2005), indicating increasing productivity over the short-term and projected as likely to continue (Good *et al.* 2005). The productivity of the Feather River and Yuba River populations and contribution to the Central Valley spring-run ESU currently is unknown.

Spatial Structure. Spring-run Chinook salmon presence has been reported more frequently in several upper Central Valley creeks, but the sustainability of these runs is unknown. Butte Creek spring-run Chinook salmon cohorts have recently utilized all currently available habitat in the creek; and it is unknown if individuals have opportunistically migrated to other systems. The spatial structure of the spring-run Chinook salmon ESU has been reduced with the extirpation of all San Joaquin River basin spring-run Chinook salmon populations.

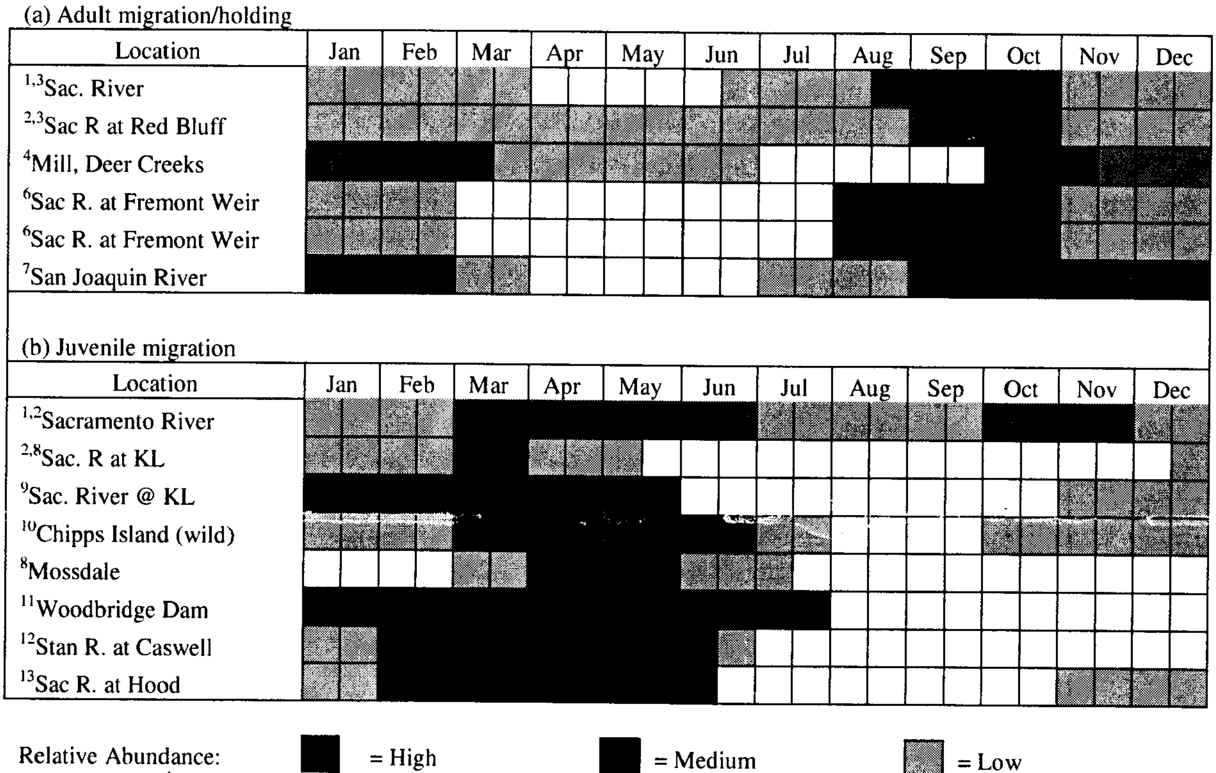
Diversity. The Central Valley spring-run Chinook salmon ESU is comprised of two genetic complexes. Analysis of natural and hatchery spring-run Chinook salmon stocks in the Central Valley indicates that the southern Cascades spring-run Chinook salmon population complex (Mill, Deer, and Butte creeks) retains genetic integrity. The genetic integrity of the Sierra Nevada spring-run Chinook salmon population complex has been somewhat compromised. The Feather River spring-run have Chinook salmon introgressed with the fall-run Chinook salmon, and it appears that the Yuba River population may have been impacted by FRH fish straying into the Yuba River. Additionally, the diversity of the spring-run Chinook salmon ESU has been further reduced with the loss of the San Joaquin River basin spring-run Chinook salmon populations.

2. Central Valley Steelhead

Steelhead can be divided into two life history types, summer-run steelhead and winter-run steelhead, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Only winter steelhead currently are found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s [Interagency Ecological Program (IEP) Steelhead Project Work Team 1999]. At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity River systems (McEwan and Jackson 1996).

Central Valley steelhead generally leave the ocean from August through April (Busby *et al.* 1996), and spawn from December through April with peaks from January though March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961, McEwan and Jackson 1996; see Table 6 in text). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches at river mouths, and associated lower water temperatures. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Barnhart *et al.* 1986, Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby *et al.* 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby *et al.* 1996). Although one-time spawners are the great majority, Shapovalov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

Table 6. The temporal occurrence of adult (a) and juvenile (b) Central Valley steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance.



Sources: [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [5]Hallock *et al.* 1957; [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2003; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980, 1997.

Spawning occurs during winter and spring months. The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51 °F. Fry emerge from the gravel usually about 4 to 6 weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). Newly emerged fry move to the shallow, protected areas associated with the stream margin (McEwan and Jackson 1996) and they soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although YOY also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991).

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating Central Valley steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002).

Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall. Nobriga and Cadrett (2003) also have verified these temporal findings based on analysis of captures at Chipps Island.

Historic Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially (see Appendix B: Figure 6). Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations.

Nobriga and Cadrett (2003) compared CWT and untagged (wild) steelhead smolt catch ratios at Chipps Island trawl from 1998 through 2001 to estimate that about 100,000 to 300,000 steelhead juveniles are produced naturally each year in the Central Valley. In the *Updated Status Review of West Coast Salmon and Steelhead* (Good *et al.* 2005), the Biological Review Team (BRT) made the following conclusion based on the Chipps Island data:

> "If we make the fairly generous assumptions (in the sense of generating large estimates of spawners) that average fecundity is 5,000 eggs per female, 1 percent of eggs survive to reach Chipps Island, and 181,000 smolts are produced (the 1998-2000 average), about 3,628 female steelhead spawn naturally in the entire Central Valley. This can be compared with McEwan's (2001) estimate of 1 million to 2 million spawners before 1850, and 40,000 spawners in the 1960s".

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill Creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks and a few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996). Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good *et al.* 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Until recently, Central Valley steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001). Zimmerman *et al.* (2008) has documented Central Valley steelhead in the Stanislaus, Tuolumne and Merced Rivers based on otilith microchemistry.

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al.* 2005). CDFG staff has prepared catch summaries for juvenile migrant Central Valley steelhead on the San Joaquin River near Mossdale which represents migrants from the Stanislaus, Tuolumne, and Merced Rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Letter from Dean Marston, CDFG, to Michael Aceituno, NMFS, 2004). The documented returns on the order of single fish in these tributaries suggest that existing populations of Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin Rivers are severely depressed (see Appendix B: Figure 7).

Lindley *et al.* (2006) indicated that prior population census estimates completed in the 1990s found the Central Valley steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good *et al.* (2005) indicated the decline was continuing as evidenced by new information (Chipps Island trawl data). Central Valley steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates. The future of Central Valley steelhead is uncertain due to limited data concerning their status. However, Lindley *et al.* (2007), citing evidence presented by Yoshiyama *et al.* (1996); McEwan (2001); and Lindley *et al.* (2006), concluded that there is sufficient evidence to suggest that the DPS is at moderate to high risk of extinction.

Viable Salmonid Population Summary for CV Steelhead

Abundance. All indications are that natural Central Valley steelhead have continued to decrease in abundance and in the proportion of natural fish over the past 25 years (Good *et al.* 2005); the long-term trend remains negative. There has been little steelhead population monitoring, despite 100 percent marking of hatchery steelhead since 1998. Hatchery production and returns are dominant over natural fish and include significant numbers of non-DPS-origin Eel River steelhead stock.

Productivity. An estimated 100,000 to 300,000 natural juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good *et al.* 2005). Concurrently, one million in-DPS hatchery steelhead smolts and another half million out-of-DPS hatchery steelhead smolts are released annually in the Central Valley. The estimated ratio of nonclipped to clipped steelhead has decreased from 0.3 percent to less than 0.1 percent, with a net decrease to one-third of wild female spawners from 1998 to 2000 (Good *et al.* 2005).

Spatial Structure. Steelhead appear to be well-distributed where found throughout the Central Valley (Good *et al.* 2005). Until recently, there was very little documented evidence of steelhead due to the lack of monitoring efforts. Since 2000, steelhead have been confirmed in the Stanislaus and Calaveras rivers.

Diversity. Analysis of natural and hatchery steelhead stocks in the Central Valley reveal genetic structure remaining in the DPS (Nielsen *et al.* 2003). There appears to be a great amount of gene flow among upper Sacramento River basin stocks, due to the post-dam, lower basin distribution of steelhead and management of stocks. Recent reductions in natural population sizes have created genetic bottlenecks in several Central Valley steelhead stocks (Good *et al.* 2005; Nielsen *et al.* 2003). The out-of-basin steelhead stocks of the Nimbus and Mokelumne River hatcheries are not included in the Central Valley steelhead DPS.

3. Southern Distinct Population Segment of North American Green Sturgeon

In North America, spawning populations of green sturgeon are currently found in only three river systems: the Sacramento and Klamath rivers in California and the Rogue River in southern Oregon. Green sturgeon are known to range from Baja California to the Bering Sea along the North American continental shelf. Data from commercial trawl fisheries and tagging studies indicate that the green sturgeon occupy waters within the 110 meter contour (Erickson and Hightower 2007). During the late summer and early fall, subadults and nonspawning adult green sturgeon frequently can be found aggregating in estuaries along the Pacific coast (Emmett *et al.* 1991, Moser and Lindley 2007). Particularly large concentrations of green sturgeon from both the northern and southern populations occur in the Columbia River estuary, Willapa Bay, Grays Harbor and Winchester Bay, with smaller aggregations in Humboldt Bay, Tillamook Bay, Nehalem Bay,and San Francisco and San Pablo Bays (Emmett *et al* 1991, Moyle *et al.* 1992, and Beamesderfer *et al.* 2007). Lindley *et al.* (2008) reported that green sturgeon make seasonal migratory movements along the west coast of North America, overwintering north of Vancouver Island and south of Cape Spencer, Alaska. Individual fish from the Southern DPS of green sturgeon have been detected in these seasonal aggregations. Information regarding the migration and habitat use of the Southern DPS of green sturgeon has recently emerged. Lindley (2006) presented preliminary results of large-scale green sturgeon migration studies, and verified past population structure delineations based on genetic work and found frequent large-scale migrations of green sturgeon along the Pacific Coast. This work was further expanded by recent tagging studies of green sturgeon conducted by Erickson and Hightower (2007) and Lindley *et al.* (2008). To date, the data indicates that North American green sturgeon are migrating considerable distances up the Pacific Coast into other estuaries, particularly the Columbia River estuary. This information also agrees with the results of previous green sturgeon tagging studies (CDFG 2002), where CDFG tagged a total of 233 green sturgeon in the San Pablo Bay estuary between 1954 and 2001. A total of 17 tagged fish were recovered: 3 in the Sacramento-San Joaquin Estuary, 2 in the Pacific Ocean off of California, and 12 from commercial fisheries off of the Oregon and Washington coasts. Eight of the 12 recoveries were in the Columbia River estuary (CDFG 2002).

The Southern DPS of green sturgeon includes all green sturgeon populations south of the Eel River, with the only known spawning population being in the Sacramento River. Green sturgeon life history can be broken down into four main stages: eggs and larvae, juveniles, sub-adults, and sexually mature adults. Sexually mature adults are those fish that have fully developed gonads and are capable of spawning. Female green sturgeon are typically 13 to 27 years old when sexually mature and have a total body length (TL) ranging between 145 and 205 cm at sexual maturity (Nakamoto *et al. 1995*, Van Eenennaam *et al.* 2006). Male green sturgeon become sexually mature at a younger age and smaller size than females. Typically, male green sturgeon reach sexual maturity between 8 and 18 years of age and have a TL ranging between 120 cm to 185 cm (Nakamoto *et al. 1995*, Van Eenennaam *et al.* 2006). The variation in the size and age of fish upon reaching sexual maturity is a reflection of their growth and nutritional history, genetics, and the environmental conditions they were exposed to during their early growth years. Adult green sturgeon are believed to feed primarily upon benthic invertebrates such as clams, mysid shrimp, grass shrimp, and amphipods (Radtke 1966). Adult sturgeon caught in Washington state waters were found to have fed on Pacific sand lance (*Ammodytes hexapterus*) and callianassid shrimp (Moyle *et al.* 1992). It is unknown what forage species are consumed by adults in the Sacramento River upstream of the Delta.

Adult green sturgeon are gonochoristic (sex genetically fixed), oviparous and iteroparous. They are believed to spawn every 2 to 5 years (Beamesderfer *et al.* 2007). Upon maturation of their gonadal tissue, but prior to ovulation or spermiation, the sexually mature fish enter freshwater and migrate upriver to their spawning grounds. The remainder of the adult's life is generally spent in the ocean or near-shore environment (bays and estuaries) without venturing upriver into freshwater. Younger females may not spawn the first time they undergo oogenesis and subsequently they reabsorb their gametes without spawning. Adult female green sturgeon produce between 60,000 and 140,000 eggs, depending on body size, with a mean egg diameter of 4.3 mm (Moyle *et al.* 1992, Van Eenennaam *et al.* 2001). They have the largest egg size of any sturgeon, and the volume of yolk ensures an ample supply of energy for the developing embryo. The outside of the eggs are adhesive, and are more dense than than those of white sturgeon (Kynard *et al.* 2005, Van Eenennaam *et al.* 2009). Adults begin their upstream spawning migrations into freshwater in late February with spawning occuring between March and July (CDFG 2002. Heublin 2006, Heublin *et al.* 2009, Vogel 2008). Peak spawning is believed to occur between April and June in deep, turbulent, mainstem channels over large cobble and rocky substrates with crevices and interstices. Females broadcast spawn their eggs over this substrate, while the male releases its milt (sperm) into the water column. Fertilization occurs externally in the water column and the fertilized eggs sink into the interstices of the substrate where they develop further (Kynard *et al.* 2005, Heublin *et al.* 2009).

Known historic and current spawning occurs in the Sacramento River (Adams *et al.* 2002, Beamesderfer *et al.* 2004, Adams *et al.* 2007). Currently, Keswick and Shasta dams on the mainstem of the Sacramento River block passage to the upper river. Although no historical accounts exist for identified green sturgeon spawning occuring above the current dam sites, suitable spawning habitat existed and the geographic extent of spawning has been reduced due to the impassable barriers constructed on the river.

Spawning on the Feather River is suspected to have occurred in the past due to the continued presence of adult green sturgeon in the river below Oroville Dam. This continued presence of adults below the dam suggests that fish are trying to migrate to upstream spawning areas now blocked by the dam, which was constructed in 1968.

Spawning in the San Joaquin River system has not been recorded historically or observed recently, but alterations of the San Joaquin River and its tributaries (Stanislaus, Tuolumne, and Merced rivers) occurred early in the European settlement of the region. During the latter half of the 1800s, impassable barriers were built on these tributaries where the water courses left the foothills and entered the valley floor. Therefore, these low elevation dams have blocked potentially suitable spawning habitats located further upstream for approximately a century. Additional destruction of riparian and stream channel habitat by industrialized gold dredging further disturbed any valley floor habitat that was still available for sturgeon spawning. Additional impacts to the watershed include the increased loads of selenium entering the system through agricultural practices in the western side of the San Joaquin Valley. Green sturgeon have recently been identified by UC Davis researchers as being highly sensitive to selenium levels. Currently, only white sturgeon have been encountered in the San Joaquin River system upstream of the Delta, and adults have been captured by sport anglers as far upstream on the San

Joaquin River as Hills Ferry and Mud Slough which are near the confluence of the Merced River with the mainstem San Joaquin River (2007 sturgeon report card - CDFG 2008)

Kelly *et al.* (2007) indicated that green sturgeon enter the San Francisco Estuary during the spring and remain until autumn (see Table 7 in text). The authors studied the movement of adults in the San Francisco Estuary and found them to make significant long-distance movements with distinct directionality. The movements were not found to be related to salinity, current, or temperature, and Kelly *et al.* (2007) surmised that they are related to resource availability and foraging behavior. Recent acoustical tagging studies on the Rogue River (Erickson *et al.* 2002) have shown that adult green sturgeon will hold for as much as 6 months in deep (> 5m), low gradient reaches or off channel sloughs or coves of the river during summer months when water temperatures were between 15°C and 23°C. When ambient temperatures in the river dropped in autumn and early winter (<10°C) and flows increased, fish moved downstream and into the ocean. Erickson *et al.* (2002) surmised that this holding in deep pools was to conserve energy and utilize abundant food resources. Benson *et al.* (2007) found similar behavior on the Klamath and Trinity River systems with adult sturgeon acoustically tagged during their spawning migrations. Most fish held over the summer in discrete locations characterized by deep, low velocity pools until late fall or early winter when river flows increased with the first storms of the rainy season. Fish then moved rapidly downstream and out of the system. Recent data gathered from acoustically tagged adult green sturgeon revealed comparable behavior by adult fish on the Sacramento River based on the positioning of adult green sturgeon in holding pools on the Sacramento River above the Glenn Colusa Irrigation District (GCID) diversion (RM 205). Studies by Heublin (2006, 2009) and Vogel (2008) have documented the presence of adults in the Sacramento River during the spring and through the fall into the early winter months. These fish hold in upstream locations prior to their emigration from the system later in the year. Like the Rogue and Klamath river systems, downstream migration appears to be triggered by increased flows, decreasing water temperatures, and occurs rapidly once initiated. It should also be noted that some adults rapidly leave the system following their suspected spawning activity and renter the ocean only in early summer (Heublin 2006). This behavior has also been observed on the other spawning rivers (Benson *et al.* 2007) but may have been an artifact of the stress of the tagging procedure in that study.

Eggs and Larvae. Currently spawning appears to occur primarily above RBDD, based on the recovery of eggs and larvae at the dam in monitoring studies (Gaines and Martin 2002, Brown 2007). Green sturgeon larvae hatch from fertilized eggs after approximately 169 hours at a water temperature of 59°F (Van Eenennaam *et al.* 2001, Deng *et al.* 2002), which is similar to the sympatric white sturgeon development rate (176 hours). Studies conducted at the University of California, Davis by Van Eenennaam *et al.* (2005) indicated that an optimum range of water temperature for egg development ranged between 57.2°F and 62.6°F. Temperatures over 23 °C resulted in 100 percent mortality of fertilized eggs before hatching. Eggs incubated at water temperatures between 63.5°F and 71.6°F resulted in elevated mortalities and an increased occurrence of morphological abnormalities in those eggs that did hatch. At incubation temperatures below 57.2°F, hatching mortality also increased significantly, and morphological abnormalities increased slightly, but not statistically so.

Newly hatched green sturgeon are approximately 12.5 to 14.5 mm in length and have a large ovoid yolk sac that supplies nutritional energy until exogenous feeding occurs. These yolksac larvae are less developed in their morphology than older juveniles and external morphology resembles a "tadpole" with a continuous fin fold on both the dorsal and ventral sides of the caudal trunk. The eyes are well developed with differentiated lenses and pigmentation.

Olfactory and auditory vesicles are present while the mouth and respiratory structures are only shallow clefts on the head. At 10 days of age, the yolk sac has become greatly reduced in size and the larvae initiates exogenous feeding through a functional mouth. The fin folds have become more developed and formation of fin rays begins to occur in all fin tissues. By 45 days of age, the green sturgeon larvae have completed their metamorphosis, which is characterized by the development of dorsal, lateral, and ventral scutes, elongation of the barbels, rostrum, and caudal peduncle, reabsorption of the caudal and ventral fin folds, and the development of fin rays. The juvenile fish resembles the adult form, including the dark olive coloring, with a dark mid-ventral stripe (Deng *et al.* 2002) and are approximately 75 mm TL. At this stage of development, the fish are considered juveniles and are no longer larvae.

Green sturgeon larvae do not exhibit the initial pelagic swim–up behavior characteristic of other *acipenseridae*. The are strongly oriented to the bottom and exhibit nocturnal activity patterns. After 6 days, the larvae exhibit nocturnal swim-up activity (Deng *et al.* 2002) and nocturnal downstream migrational movements (Kynard *et al.* 2005). Juvenile fish continue to exhibit nocturnal behavioral beyond the metamorphosis from larvae to juvenile stages. Kynard *et al.*'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first 6 months of life. When ambient water temperatures reached 46.4°F, downstream migrational behavior diminished and holding behavior increased. This data suggests that 9 to 10 month old fish would hold over in their natal rivers during the ensuing winter following hatching, but at a location downstream of their spawning grounds.

Green sturgeon juveniles tested under laboratory conditions had optimal bioenergetic performance (*i.e.* growth, food conversion, swimming ability) between 59°F and 66.2°F under either full or reduced rations (Mayfield and Cech 2004). This temperature range overlaps the egg incubation temperature range for peak hatching success previously discussed. Ambient water temperature conditions in the Rogue and Klamath River systems range from 39°F to approximately 75.2°F. The Sacramento River has similar temperature profiles, and, like the previous two rivers, is a regulated system with several dams controlling flows on its mainstem (Shasta and Keswick dams), and its tributaries (Whiskeytown, Oroville, Folsom, and Nimbus dams).

Larval and juvenile green sturgeon are subject to predation by both native and introduced fish species. Prickly sculpin (*Cottus asper*) have been shown to be an effective predator on the larvae of sympatric white sturgeon (Gadomski and Parsley 2005). This study also indicated that the lowered turbidity found in tailwater streams and rivers due to dams increased the effectiveness of sculpin predation on sturgeon larvae under laboratory conditions.

Larval and juvenile sturgeons have been caught in traps at two sites in the upper Sacramento River: below the RBDD (rm 243) and from the GCID pumping plant (rm 205) (CDFG 2002). Larvae captured at the RBDD site are typically only a few days to a few weeks old, with lengths ranging from 24 to 31 mm. This body length is equivalent to 15 to 28 days post hatch as determined by Deng *et al.* (2002). Recoveries of larvae at the RBDD rotary screw traps (RSTs) occur between late April/early May and late August with the peak of recoveries occurring in June (1995-1999 and 2003–2008 data). The mean yearly total length of post-larval green sturgeon captured in the GCID rotary screw trap, approximately 30 miles downstream of RBDD, ranged from 33 mm to 44 mm between 1997 and 2005 (CDFG, 2002) indicating they are approximately 3-4 weeks old (Van Eenennaam *et al.* 2001, Deng *et al.* 2002). Taken together, the average length of larvae captured at the two monitoring sites indicate that fish were hatched upriver of the monitoring site and drifted downstream over the course of 2 to 4 weeks of growth. According to the CDFG document commenting on the NMFS proposal to list the southern DPS (CDFG 2002), some green sturgeon rear to larger sizes above RBDD, or move back to this location after spending time downstream. Two sturgeon between 180 and 400 mm TL were captured in the rotary-screw trap during 1999 and green sturgeon within this size range have been impinged on diffuser screens associated with a fish ladder at RBDD (K. Brown, USFWS, pers. comm. as cited in CDFG 2002).

Table 7. The temporal occurrence of (a) adult, (b) larval (c) juvenile and (d) subadult coastal migrant Southern DPS of green sturgeon. Locations emphasize the Central Valley of California. Darker shades indicate months of greatest relative abundance.

(a) Adult-sexually mature (≥145 – 205 cm TL for females and ≥ 120 – 185 cm TL old for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Sac. River[a,b,c,i]												
SF Bay Estuary[d,h,i]												

(b) Larval and juvenile (≤10 months old)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RBDD, Sac River[e]												
GCID, Sac River[e]												

(c) Older Juvenile (> 10 months old and ≤3 years old)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
South Delta*[f]												
Sac-SJ Delta[f]												
Sac-SJ Delta[e]												
Suisun Bay[e]												

(d) Sub-Adult/non-sexually mature (approx. 75 cm to 145 cm for females and 75 to 120 cm for males)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pacific Coast[c,g]												

Relative Abundance: ■ = High ■ = Medium ▒ = Low

* Fish Facility salvage operations

Sources: [a]USFWS (2002); [b]Moyle *et al.* (1992); [c]Adams *et al.* (2002) and NMFS (2005); [d]Kelly *et al.* (2007); [e]CDFG (2002); [f]IEP Relational Database, fall midwater trawl green sturgeon captures from 1969 to 2003; [g]Nakamoto *et al.* (1995); [h]Heublein (2006); [i]CDFG Draft Sturgeon Report Card (2007)

Juvenile green sturgeon have been salvaged at the Harvey O. Banks Pumping Plant and the John E. Skinner Fish Collection Facility (Fish Facilities) in the South Delta, and captured in trawling studies by CDFG during all months of the year (CDFG 2002). The majority of these fish were between 200 and 500 mm, indicating they were from 2 to 3 years of age based on Klamath River age distribution work by Nakamoto *et al.* (1995). The lack of a significant proportion of juveniles smaller than approximately 200 mm in Delta captures indicates that juveniles of the Southern DPS of green sturgeon likely hold in the mainstem Sacramento River, as suggested by Kynard *et al.* (2005).

Population abundance information concerning the Southern DPS green sturgeon is described in the NMFS status reviews (Adams *et al.* 2002, NMFS 2005a). Limited population abundance information comes from incidental captures of North American green sturgeon from the white sturgeon monitoring program by the CDFG sturgeon tagging program (CDFG 2002). By comparing ratios of white sturgeon to green sturgeon captures, CDFG provides estimates of adult and sub-adult North American green sturgeon abundance. Estimated abundance between 1954 and 2001 ranged from 175 fish to more than 8,000 per year and averaged 1,509 fish per year. Unfortunately, there are many biases and errors associated with these data, and CDFG does not consider these estimates reliable. Fish monitoring efforts at RBDD and GCID on the upper Sacramento River have captured between 0 and 2,068 juvenile North American green sturgeon per year (Adams *et al.* 2002). The only existing information regarding changes in the abundance of the Southern DPS of green sturgeon includes changes in abundance at the John E. Skinner Fish Facility between 1968 and 2001 (see Appendix A Table 8 and Appendix B Figure 8a). The average number of North American green sturgeon taken per year at the State Facility prior to 1986 was 732; from 1986 on, the average per year was 47 (April 5, 2005 70 FR 17386). For the Harvey O. Banks Pumping Plant, the average number prior to 1986 was 889; from 1986 to 2001 the average was 32 (April 5, 2005 70 FR 17386). In light of the increased exports, particularly during the previous 10 years, it is clear that the abundance of the Southern DPS green sturgeon is dropping. Additional analysis of North American green and white sturgeon taken at the Fish Facilities indicates that take of both North American green and white sturgeon per acre-foot of water exported has decreased substantially since the 1960s (April 5, 2005 70 FR 17386). Catches of sub-adult and adult North American green sturgeon by the IEP between 1996 and 2004 ranged from 1 to 212 green sturgeon per year (212 occurred in 2001), however, the portion of the Southern DPS of North American green sturgeon is unknown as these captures were primarily located in San Pablo Bay which is known to consist of a mixture of Northern and Southern DPS North American green sturgeon. Recent spawning population estimates using sibling based genetics by Israel (2006b) indicates spawning populations of 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (with an average of 71).

As described previously, the majority of spawning by green sturgeon in the Sacramento River system appears to take place above the location of RBDD. This is based on the length and estimated age of larvae captured at RBDD (approximately 2-3 weeks of age) and GCID (downstream, approximately 3-4 weeks of age) indicating that hatching occurred above the sampling location. Note that there are many assumptions with this interpretation (*i.e.*, equal sampling efficiency and distribution of larvae across channels) and this information should be considered cautiously.

Available information on green sturgeon indicates that, as with winter-run, the mainstem Sacramento River may be the last viable spawning habitat (Good *et al.* 2005) for the Southern DPS of green sturgeon. Lindley *et al.* (2007) pointed out that an ESU represented by a single population at moderate risk is at a high risk of extinction over the long term. Although the extinction risk of the Southern DPS of green sturgeon has not been assessed, NMFS believes that the extinction risk has increased because there is only one known population, within the mainstem Sacramento River.

Population Viability Summary for the Southern DPS of North American Green Sturgeon

The Southern DPS of North American green sturgeon has not been analyzed to characterize the status and viability as has been done in recent efforts for Central Valley salmonid populations (Lindley *et al.* 2006, Good *et al.* 2005). NMFS assumes that the general categories for assessing salmonid population viability will also be useful in assessing the viability of the Southern DPS of green sturgeon. The following summary has been compiled from the best available data and information on North American green sturgeon to provide a general synopsis of the viability parameters for this DPS.

Abundance. Currently, there are no reliable data on population sizes, and data on population trends is also lacking. Fishery data collected at Federal and State pumping facilities in the Delta indicate a decreasing trend in abundance between 1968 and 2006 (70 FR 17386). .

Productivity. There is insufficient information to evaluate the productivity of green sturgeon. However, as indicated above, there appears to be a declining trend in abundance, which indicates low to negative productivity.

Spatial Structure. Current data indicates that the Southern DPS of North American green sturgeon is comprised of a single spawning population in the Sacramento River. Although some individuals have been observed in the Feather and Yuba rivers, it is not yet known if these fish represent separate spawning populations. Therefore, the apparent presence of a single reproducing population puts the DPS at risk, due to extremely tenuous spatial structure.

Diversity. Green sturgeon genetic analyses shows strong differentiation between northern and southern populations, and therefore, the species was divided into Northern and Southern DPSs. However, the genetic diversity of the Southern DPS is not well understood.

C. Definition of Critical Habitat Condition and Function for Species' Conservation

The designated critical habitat for Sacramento River winter-run Chinook salmon includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge. In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. In the areas westward of Chipps Island, critical habitat includes the estuarine water column and essential foraging habitat and food resources used by Sacramento River winter-run Chinook salmon as part of their juvenile emigration or adult spawning migration.

Critical habitat was designated for Central Valley spring-run Chinook salmon and Central Valley steelhead on September 2, 2005 (70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon includes stream reaches such as those of the Feather and Yuba Rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear Creeks, the Sacramento River, as well as portions of the northern Delta. Critical habitat for Central Valley steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba Rivers, and Deer, Mill, Battle, and Antelope Creeks in the Sacramento River basin; the San Joaquin River, including its tributaries, and the waterways of the Delta. Critical habitat includes the stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent will be defined by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain; it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (Bain and Stevenson 1999; 70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon and steelhead is defined as specific areas that contain the primary constituent elements (PCE) and physical habitat elements essential to the conservation of the species. Following are the inland habitat types used as PCEs for Central Valley spring-run Chinook salmon and Central Valley steelhead, and as physical habitat elements for Sacramento River winter-run Chinook salmon. Critical habitat for the Southern DPS of the North American green sturgeon has been proposed (September 8, 2008), and is expected to be finalized by early summer of 2009.

PCE for Central Valley Spring-run Chinook salmon and Central Valley steelhead include:

1. Spawning Habitat

Freshwater spawning sites are those with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. Most spawning habitat in the Central Valley for Chinook salmon and steelhead is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam. Central Valley spring-run Chinook salmon also spawn on the mainstem Sacramento River between RBDD and Keswick Dam and in tributaries such as Mill, Deer, and Butte Creeks (however, little spawning activity has been recorded in recent years on the Sacramento River mainstem for spring-run Chinook salmon). Spawning habitat for Central Valley steelhead is similar in nature to the requirements of Chinook salmon, primarily occurring in reaches directly below dams (*i.e.*, above RBDD on the Sacramento River) on perennial watersheds throughout the Central Valley. These reaches can be subjected to variations in flows and temperatures, particularly over the summer months, which can have adverse effects upon salmonids spawning below them. Even in degraded reaches, spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of listed salmonids.

2. Freshwater Rearing Habitat

Freshwater rearing sites are those with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat condition is strongly affected by habitat complexity, food supply, and the presence of predators of juvenile salmonids. Some complex, productive habitats with floodplains remain in the system (*e.g.*, the lower Cosumnes River, Sacramento River reaches with setback levees [*i.e.*, primarily located upstream of the City of Colusa]) and flood bypasses (*i.e.*, Yolo and Sutter bypasses). However, the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento-San Joaquin system typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. Freshwater rearing habitat also has a high conservation value even if the current conditions are significantly degraded from their natural state. Juvenile life stages of salmonids are dependant on the function of this habitat for successful survival and recruitment.

3. Freshwater Migration Corridors

Ideal freshwater migration corridors are free of migratory obstructions, with water quantity and quality conditions that enhance migratory movements. They contain natural cover such as riparian canopy structure, submerged and overhanging large woody objects, aquatic vegetation, large rocks, and boulders, side channels, and undercut banks which augment juvenile and adult mobility, survival, and food supply. Migratory corridors are downstream of the spawning areas and include the lower mainstems of the Sacramento and San Joaquin rivers and the Delta. These corridors allow the upstream passage of adults, and the downstream emigration of outmigrant juveniles. Migratory habitat condition is strongly affected by the presence of barriers, which can include dams (*i.e.*, hydropower, flood control, and irrigation flashboard dams), unscreened or poorly screened diversions, degraded water quality, or behavioral impediments to migration. For successful survival and recruitment of salmonids, freshwater migration corridors must function sufficiently to provide adequate passage. For this reason, freshwater migration corridors are considered to have a high conservation value even if the migration corridors are significantly degraded compared to their natural state.

4. Estuarine Areas

Estuarine areas free of migratory obstructions with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water are included as a PCE. Natural cover such as submerged and overhanging large woody material, aquatic vegetation, and side channels, are suitable for juvenile and adult foraging. Estuarine areas are considered to have a high conservation value as they provide factors which function to provide predator avoidance and as a transitional zone to the ocean environment.

Critical habitat for the Southern DPS of green sturgeon has been proposed for the estuarine waters of the Delta. It contains the following elements:

1. Food Resources

Abundant food items within estuarine habitats and substrates for juvenile, subadult, and adult life stages are required for the proper functioning of this PCE for green sturgeon. Prey species for juvenile, subadult, and adult green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fish, including crangonid shrimp, callianassid shrimp, burrowing thalassinidean shrimp, amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. These prey species are critical for the rearing, foraging, growth, and development of juvenile, subadult, and adult green sturgeon within the bays and estuaries.

2. Water Flow

Within bays and estuaries adjacent to the Sacramento River (*i.e.*, the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds is required. Sufficient flows are needed to attract adult green sturgeon to the Sacramento River from the bay and to initiate the upstream spawning migration into the upper river.

3. Water Quality

Adequate water quality, including temperature, salinity, oxygen content, and other chemical characteristics, is necessary for normal behavior, growth, and viability of all life stages. Suitable water temperatures for juvenile green sturgeon should be below 24°C (75°F). At temperatures above 24°C, juvenile green sturgeon exhibit decreased swimming performance (Mayfield and Cech 2004) and increased cellular stress (Allen *et al.* 2006). Suitable salinities in the estuary range from brackish water (10 parts per thousand - ppt) to salt water (33 ppt). Juveniles transitioning from brackish to salt water can tolerate prolonged exposure to salt water salinities, but may exhibit decreased growth and activity levels (Allen and Cech 2007), whereas subadults and adults tolerate a wide range of salinities (Kelly *et al.* 2007). Subadult and adult green sturgeon occupy a wide range of DO levels (Kelly *et al.* 2007, Moser and Lindley 2007). Adequate levels of DO are also required to support oxygen consumption by juveniles (ranging from 61.78 to 76.06 mg O_2 hr^{-1} kg^{-1}, Allen and Cech 2007). Suitable water quality also includes water free of contaminants (*e.g.*, organochlorine pesticides, poly aromatic hydrocarbons (PAHs), or elevated levels of heavy metals) that may disrupt the normal development of juvenile life stages, or the growth, survival, or reproduction of subadult or adult stages.

4. Migratory Corridor

Safe and unobstructed migratory pathways are necessary for the safe and timely passage of adult, sub-adult, and juvenile fish within the region's different estuarine habitats and between the upstream riverine habitat and the marine habitats. Within the waterways comprising the Delta, and bays downstream of the Sacramento River, safe and unobstructed passage is needed for juvenile green sturgeon during the rearing phase of their life cycle. Rearing fish need the ability to freely migrate from the river through the estuarine waterways of the delta and bays and eventually out into the ocean. Passage within the bays and the Delta is also critical for adults and subadults for feeding and summer holding, as well as to access the Sacramento River for their upstream spawning migrations and to make their outmigration back into the ocean. Within bays and estuaries outside of the Delta and the areas comprised by Suisun, San Pablo, and San Francisco bays, safe and unobstructed passage is necessary for adult and subadult green sturgeon to access feeding areas, holding areas, and thermal refugia, and to ensure passage back out into the ocean.

5 Water Depth

A diversity of depths is necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Tagged adults and subadults within the San Francisco Bay estuary primarily occupied waters over shallow depths of less than 10 m, either swimming near the surface or foraging along the bottom (Kelly *et al.* 2007). In a study of juvenile green sturgeon in the Delta, relatively large numbers of juveniles were captured primarily in shallow waters from 3 – 8 feet deep, indicating juveniles may require shallower depths for rearing and foraging (Radtke 1966). Thus, a diversity of depths is important to support different life stages and habitat uses for green sturgeon within estuarine areas.

6 Sediment Quality

Sediment quality (*i.e.*, chemical characteristics) is necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of contaminants (*e.g.*, elevated levels of selenium, PAHs, and organochlorine pesticides) that can cause negative effects on all life stages of green sturgeon.

D. Factors Impacting Listed Species

1. Habitat Blockage

Hydropower, flood control, and water supply dams of the CVP, SWP, and other municipal and private entities have permanently blocked or hindered salmonid access to historical spawning and rearing grounds. Clark (1929) estimated that originally there were 6,000 linear miles of salmon habitat in the Central Valley system and that 80 percent of this habitat had been lost by 1928. Yoshiyama *et al.* (1996) calculated that roughly 2,000 linear miles of salmon habitat was actually available before dam construction and mining, and concluded that 82 percent is not accessible today.

As a result of migrational barriers, winter-run Chinook salmon, spring-run Chinook salmon, and steelhead populations have been confined to lower elevation mainstems that historically only were used for migration. Population abundances have declined in these streams due to decreased quantity and quality of spawning and rearing habitat. Higher temperatures at these lower elevations during late-summer and fall are also a major stressor to adult and juvenile salmonids. According to Lindley *et al.* (2004), of the four independent populations of Sacramento River winter-run Chinook salmon that occurred historically, only one mixed stock of winter-run Chinook salmon remains below Keswick Dam. Similarly, of the 18 independent populations of

Central Valley spring-run Chinook salmon that occurred historically, only three independent populations remain in Deer, Mill, and Butte creeks. Dependent populations of Central Valley spring-run Chinook salmon continue to occur in Big Chico, Antelope, Clear, Thomes, Beegum, and Stony creeks, but rely on the three extant independent populations for their continued survival. Central Valley steelhead historically had at least 81 independent populations based on Lindley *et al.*'s (2006) analysis of potential habitat in the Central Valley. However, due to dam construction, access to 38 percent of all spawning habitat has been lost as well as access to 80 percent of the historically available habitat. Green sturgeon populations would be similarly affected by these barriers and alterations to the natural hydrology. In particular, RBDD blocks access to a significant portion of the adult spawning run under current operationl procedures.

The Suisun Marsh Salinity Control Gates (SMSCG), located on Montezuma Slough, were installed in 1988, and are operated with gates and flashboards to decrease the salinity levels of managed wetlands in Suisun Marsh. The SMSCG have delayed or blocked passage of adult Chinook salmon migrating upstream (Edwards *et al.* 1996, Tillman *et al.* 1996, DWR 2002a). The effects of the SMSCG on sturgeon are unknown at this time.

2. Water Development

The diversion and storage of natural flows by dams and diversion structures on Central Valley waterways have depleted streamflows and altered the natural cycles by which juvenile and adult salmonids base their migrations. As much as 60 percent of the natural historical inflow to Central Valley watersheds and the Delta have been diverted for human uses. Depleted flows have contributed to higher temperatures, lower DO levels, and decreased recruitment of gravel and large woody debris (LWD). More uniform flows year round have resulted in diminished natural channel formation, altered foodweb processes, and slower regeneration of riparian vegetation. These stable flow patterns have reduced bedload movement (Mount 1995, Ayers 2001), caused spawning gravels to become embedded, and decreased channel widths due to channel incision, all of which has decreased the available spawning and rearing habitat below dams. The storage of unimpeded runoff in these large reservoirs also has altered the normal hydrograph for the Sacramento and San Joaquin River watersheds. Rather than seeing peak flows in these river systems following winter rain events (Sacramento River) or spring snow melt (San Joaquin River), the current hydrology has truncated peaks with a prolonged period of elevated flows (compared to historical levels) continuing into the summer dry season.

Water withdrawals, for agricultural and municipal purposes have reduced river flows and increased temperatures during the critical summer months, and in some cases, have been of a sufficient magnitude to result in reverse flows in the lower San Joaquin River (Reynolds *et al.* 1993). Direct relationships exist between water temperature, water flow, and juvenile salmonid survival (Brandes and McLain 2001). Elevated water temperatures in the Sacramento River have limited the survival of young salmon in those waters. Juvenile fall-run Chinook salmon survival in the Sacramento River is also directly related with June streamflow and June and July Delta outflow (Dettman *et al.* 1987).

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Central Valley. Thousands of small and medium-size water diversions exist along the Sacramento River, San Joaquin River, and their tributaries. Although efforts have been made in recent years to screen some of these diversions, many remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile salmonids. For example, as of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001). Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

Outmigrant juvenile salmonids in the Delta have been subjected to adverse environmental conditions created by water export operations at the CVP and SWP facilities. Specifically, juvenile salmonid survival has been reduced by the following: (1) water diversion from the mainstem Sacramento River into the Central Delta via the Delta Cross Channel; (2) upstream or reverse flows of water in the lower San Joaquin River and southern Delta waterways; (3) entrainment at the CVP/SWP export facilities and associated problems at Clifton Court Forebay; and (4) increased exposure to introduced, non-native predators such as striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), and sunfishes (*Centrarchidae* spp.).

3. Water Conveyance and Flood Control

The development of the water conveyance system in the Delta has resulted in the construction of more than 1,100 miles of channels and diversions to increase channel elevations and flow capacity of the channels (Mount 1995). Levee development in the Central Valley affects spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine habitat PCEs. As Mount (1995) indicates, there is an "underlying, fundamental conflict inherent in this channelization." Natural rivers strive to achieve dynamic equilibrium to handle a watersheds supply of discharge and sediment (Mount 1995). The construction of levees disrupts the natural processes of the river, resulting in a multitude of habitat-related effects.

Many of these levees use angular rock (riprap) to armor the bank from erosive forces. The effects of channelization, and riprapping, include the alteration of river hydraulics and cover along the bank as a result of changes in bank configuration and structural features (Stillwater Sciences 2006). These changes affect the quantity and quality of nearshore habitat for juvenile salmonids and have been thoroughly studied (USFWS 2000, Schmetterling *et al.* 2001, Garland *et al.* 2002). Simple slopes protected with rock revetment generally create nearshore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than occur along natural banks. Higher water velocities typically inhibit deposition and retention of sediment and woody debris. These changes generally reduce the range of habitat conditions typically found along natural shorelines, especially by eliminating the shallow, slow-velocity river margins used by juvenile fish as refuge and escape from fast currents, deep water, and predators (Stillwater Sciences 2006).

Prior to the 1970s, there was so much debris resulting from poor logging practices that many streams were completely clogged and were thought to have been total barriers to fish migration. As a result, in the 1960s and early 1970s it was common practice among fishery management agencies to remove woody debris thought to be a barrier to fish migration (NMFS 1996b). However, it is now recognized that too much LWD was removed from the streams resulting in a loss of salmonid habitat and it is thought that the large scale removal of woody debris prior to 1980 had major, long-term negative effects on rearing habitats for salmonids in northern California (NMFS 1996b). Areas that were subjected to this removal of LWD are still limited in the recovery of salmonid stocks; this limitation could be expected to persist for 50 to 100 years following removal of debris.

Large quantities of downed trees are a functionally important component of many streams (NMFS 1996b). LWD influences stream morphology by affecting channel pattern, position, and geometry, as well as pool formation (Keller and Swanson 1979, Bilby 1984, Robison and Beschta 1990). Reduction of wood in the stream channel, either from past or present activities, generally reduces pool quantity and quality, alters stream shading which can affect water temperature regimes and nutrient input, and can eliminate critical stream habitat needed for both vertebrate and invertebrate populations. Removal of vegetation also can destabilize marginally stable slopes by increasing the subsurface water load, lowering root strength, and altering water flow patterns in the slope.

In addition, the armoring and revetment of stream banks tends to narrow rivers, reducing the amount of habitat per unit channel length (Sweeney *et al.* 2004). As a result of river narrowing, benthic habitat decreases and the number of macroinvertebrates, such as stoneflies and mayflies, per unit channel length decreases affecting salmonid food supply.

4. Land Use Activities

Land use activities continue to have large impacts on salmonid habitat in the Central Valley watershed. Until about 150 years ago, the Sacramento River was bordered by up to 500,000 acres of riparian forest, with bands of vegetation extending outward for 4 or 5 miles (California Resources Agency 1989). Starting with the gold rush, these vast riparian forests were cleared for building materials, fuel, and to clear land for farms on the raised natural levee banks. The degradation and fragmentation of riparian habitat continued with extensive flood control and bank protection projects, together with the conversion of the fertile riparian lands to agriculture outside of the natural levee belt. By 1979, riparian habitat along the Sacramento River diminished to 11,000 to 12,000 acres, or about 2 percent of historic levels (McGill 1987). The clearing of the riparian forests removed a vital source of snags and driftwood in the Sacramento and San Joaquin River basins. This has reduced the volume of LWD input needed to form and maintain stream habitat that salmon depend on in their various life stages. In addition to this loss of LWD sources, removal of snags and obstructions from the active river channel for navigational safety has further reduced the presence of LWD in the Sacramento and San Joaquin Rivers, as well as the Delta.

Increased sedimentation resulting from agricultural and urban practices within the Central Valley is one of the primary causes of salmonid habitat degradation (NMFS 1996a). Sedimentation can adversely affect salmonids during all freshwater life stages by: clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity (Cordone and Kelley 1961), and affecting intergravel permeability and DO levels. Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival (Waters 1995).

Land use activities associated with road construction, urban development, logging, mining, agriculture, and recreation have significantly altered fish habitat quantity and quality through the alteration of streambank and channel morphology; alteration of ambient water temperatures; degradation of water quality; elimination of spawning and rearing habitat; fragmentation of available habitats; elimination of downstream recruitment of LWD; and removal of riparian vegetation, resulting in increased streambank erosion (Meehan 1991). Urban stormwater and agricultural runoff may be contaminated with herbicides and pesticides, petroleum products, sediment, *etc.* Agricultural practices in the Central Valley have eliminated large trees and logs and other woody debris that would otherwise be recruited into the stream channel (NMFS 1998a).

Since the 1850s, wetlands reclamation for urban and agricultural development has caused the cumulative loss of 79 and 94 percent of the tidal marsh habitat in the Delta downstream and upstream of Chipps Island, respectively (Conomos *et al.* 1985, Nichols *et al.* 1986, Wright and Phillips 1988, Monroe *et al.* 1992, Goals Project 1999). Prior to 1850, approximately 1400 km^2 of freshwater marsh surrounded the confluence of the Sacramento and San Joaquin Rivers, and another 800 km^2 of saltwater marsh fringed San Francisco Bay's margins. Of the original 2,200 km^2 of tidally influenced marsh, only about 125 km^2 of undiked marsh remains today. In Suisun Marsh, saltwater intrusion and land subsidence gradually has led to the decline of agricultural production. Presently, Suisun Marsh consists largely of tidal sloughs and managed wetlands for duck clubs, which first were established in the 1870s in western Suisun Marsh (Goals Project 1999). Even more extensive losses of wetland marshes occurred in the Sacramento and San Joaquin River Basins. Little of the extensive tracts of wetland marshes that existed prior to 1850 along the valley's river systems and within the natural flood basins exist today. Most has been "reclaimed" for agricultural purposes, leaving only small remnant patches.

Dredging of river channels to enhance inland maritime trade and to provide raw material for levee construction has significantly and detrimentally altered the natural hydrology and function of the river systems in the Central Valley. Starting in the mid-1800s, the Corps and other private consortiums began straightening river channels and artificially deepening them to enhance shipping commerce. This has led to declines in the natural meandering of river channels and the formation of pool and riffle segments. The deepening of channels beyond their natural depth also has led to a significant alteration in the transport of bedload in the riverine system as well as the local flow velocity in the channel (Mount 1995). The Sacramento Flood Control Project at the turn of the nineteenth century ushered in the start of large scale Corps actions in the Delta and along the rivers of California for reclamation and flood control. The creation of levees and the deep shipping channels reduced the natural tendency of the San Joaquin and Sacramento Rivers to create floodplains along their banks with seasonal inundations during the wet winter season and the spring snow melt periods. These annual inundations provided necessary habitat for rearing and foraging of juvenile native fish that evolved with this flooding process. The armored riprapped levee banks and active maintenance actions of Reclamation Districts precluded the establishment of ecologically important riparian vegetation, introduction of valuable LWD from these riparian corridors, and the productive intertidal mudflats characteristic of the undisturbed Delta habitat.

Urban stormwater and agricultural runoff may be contaminated with pesticides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other organics and nutrients (California Regional Water Quality Control Board-Central Valley Region [Regional Board] 1998) they can potentially destroy aquatic life necessary for salmonid survival (NMFS 1996a, b). Point source (PS) and non-point source (NPS) pollution occurs at almost every point that urbanization activity influences the watershed. Impervious surfaces (*i.e.*, concrete, asphalt, and buildings) reduce water infiltration and increase runoff, thus creating greater flood hazard (NMFS 1996a, b). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. A flashy discharge pattern results in increased bank erosion with subsequent loss of riparian vegetation, undercut banks and stream channel widening. In addition to the PS and NPS inputs from urban runoff, juvenile salmonids are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges.

Past mining activities routinely resulted in the removal of spawning gravels from streams, the straightening and channelization of the stream corridor from dredging activities, and the leaching of toxic effluents into streams from mining operations. Many of the effects of past mining operations continue to impact salmonid habitat today. Current mining practices include suction dredging (sand and gravel mining), placer mining, lode mining and gravel mining. Present day mining practices are typically less intrusive than historic operations (hydraulic mining); however, adverse impacts to salmonid habitat still occur as a result of present-day mining activities. Sand and gravel are used for a large variety of construction activities including base material and asphalt, road bedding, drain rock for leach fields, and aggregate mix for concrete to construct buildings and highways.

Most aggregate is derived principally from pits in active floodplains, pits in inactive river terrace deposits, or directly from the active channel. Other sources include hard rock quarries and mining from deposits within reservoirs. Extraction sites located along or in active floodplains present particular problems for anadromous salmonids. Physical alteration of the stream channel may result in the destruction of existing riparian vegetation and the reduction of available area for seedling establishment (Stillwater Sciences 2002). Loss of vegetation impacts riparian and aquatic habitat by causing a loss of the temperature moderating effects of shade and cover, and habitat diversity. Extensive degradation may induce a decline in the alluvial water table, as the banks are effectively drained to a lowered level, affecting riparian vegetation and water supply (NMFS 1996b). Altering the natural channel configuration will reduce salmonid habitat diversity by creating a wide, shallow channel lacking in the pools and cover necessary for all life stages of anadromous salmonids. In addition, waste products resulting from past and present mining activities, include cyanide (an agent used to extract gold from ore), copper, zinc, cadmium, mercury, asbestos, nickel, chromium, and lead.

Juvenile salmonids are exposed to increased water temperatures in the Delta during the late spring and summer due to the loss of riparian shading, and by thermal inputs from municipal, industrial, and agricultural discharges. Studies by DWR on water quality in the Delta over the last 30 years show a steady decline in the food sources available for juvenile salmonids and sturgeon and an increase in the clarity of the water due to a reduction in phytoplankton and zooplankton. These conditions have contributed to increased mortality of juvenile Chinook salmon, steelhead, and sturgeon as they move through the Delta.

5. Water Quality

The water quality of the Delta has been negatively impacted over the last 150 years. Increased water temperatures, decreased DO levels, and increased turbidity and contaminant loads have degraded the quality of the aquatic habitat for the rearing and migration of salmonids. The Regional Board, in its 1998 Clean Water Act §303(d) list characterized the Delta as an impaired waterbody having elevated levels of chlorpyrifos, dichlorodiphenyltrichlor (*i.e.* DDT), diazinon, electrical conductivity, Group A pesticides (aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexanes [including lindane], endosulfan and toxaphene), mercury, low DO, organic enrichment, and unknown toxicities (Regional Board 1998, 2001).

In general, water degradation or contamination can lead to either acute toxicity, resulting in death when concentrations are sufficiently elevated, or more typically, when concentrations are lower, to chronic or sublethal effects that reduce the physical health of the organism, and lessens its survival over an extended period of time. Mortality may become a secondary effect due to compromised physiology or behavioral changes that lessen the organism's ability to carry out its normal activities. For example, increased levels of heavy metals are detrimental to the health of an organism because they interfere with metabolic functions by inhibiting key enzyme activity in metabolic pathways, decrease neurological function, degrade cardiovascular output, and act as mutagens, teratogens or carcinogens in exposed organisms (Rand *et al.* 1995, Goyer 1996). For listed species, these effects may occur directly to the listed fish or to its prey base, which reduces the forage base available to the listed species.

In the aquatic environment, most anthropogenic chemicals and waste materials including toxic organic and inorganic chemicals eventually accumulate in sediment (Ingersoll 1995). Direct exposure to contaminated sediments may cause deleterious effects to listed salmonids or the threatened green sturgeon. This may occur if a fish swims through a plume of the resuspended sediments or rests on contaminated substrate and absorbs the toxic compounds through one of several routes: dermal contact, ingestion, or uptake across the gills. Elevated contaminant levels may be found in localized "hot spots" where discharge occurs or where river currents deposit sediment loads. Sediment contaminant levels can thus be significantly higher than the overlying water column concentrations (Environmental Protection Agency 1994). However, the more likely route of exposure to salmonids or sturgeon is through the food chain, when the fish feed on organisms that are contaminated with toxic compounds. Prey species become contaminated either by feeding on the detritus associated with the sediments or dwelling in the sediment itself. Therefore, the degree of exposure to the salmonids and green sturgeon depends on their trophic level and the amount of contaminated forage base they consume. Response of salmonids and green sturgeon to contaminated sediments is similar to water borne exposures.

Low DO levels frequently are observed in the portion of the Stockton deep water ship channel (DWSC) extending from Channel Point, downstream to Turner and Columbia Cuts. Over a 5-year period, starting in August 2000, a DO meter has recorded channel DO levels at Rough and Ready Island (Dock 20 of the West Complex). Over the course of this time period, there have been 297 days in which violations of the 5 mg/l DO criteria for the protection of aquatic life in the San Joaquin River between Channel Point and Turner and Columbia Cuts have occurred during the September through May migratory period for salmonids in the San Joaquin River. The data derived from the California Data Exchange Center files indicate that DO depressions occur during all migratory months, with significant events occurring from November through March when listed Central Valley steelhead adults and smolts would be utilizing this portion of the San Joaquin River as a migratory corridor (see Appendix A, Table 9).

Potential factors that contribute to these DO depressions are reduced river flows through the ship channel, released ammonia from the City of Stockton Wastewater Treatment Plant, upstream contributions of organic materials (*e.g.*, algal loads, nutrients, agricultural discharges) and the increased volume of the dredged ship channel. During the winter and early spring emigration period, increased ammonia concentrations in the discharges from the City of Stockton Waste Water Treatment Facility lowers the DO in the adjacent DWSC near the West Complex. In addition to the adverse effects of the lowered DO on salmonid physiology, ammonia is in itself toxic to salmonids at low concentrations. Likewise, adult fish migrating upstream will encounter lowered DO in the DWSC as they move upstream in the fall and early winter due to low flows and excessive algal and nutrient loads coming downstream from the upper San Joaquin River watershed. Levels of DO below 5 mg/L have been reported as delaying or blocking fall-run Chinook salmon in studies conducted by Hallock *et al.* (1970).

6. Hatchery Operations and Practices

Five hatcheries currently produce Chinook salmon in the Central Valley and four of these also produce steelhead. Releasing large numbers of hatchery fish can pose a threat to wild Chinook salmon and steelhead stocks through genetic impacts, competition for food and other resources between hatchery and wild fish, predation of hatchery fish on wild fish, and increased fishing pressure on wild stocks as a result of hatchery production (Waples 1991). The genetic impacts of artificial propagation programs in the Central Valley primarily are caused by straying of hatchery fish and the subsequent interbreeding of hatchery fish with wild fish. In the Central Valley, practices such as transferring eggs between hatcheries and trucking smolts to distant sites for release contribute to elevated straying levels [Department of the Interior (DOI) 1999]. For example, Nimbus Hatchery on the American River rears Eel River steelhead stock and releases these fish in the Sacramento River basin. One of the recommendations in the Joint Hatchery Review Report (NMFS and CDFG 2001) was to identify and designate new sources of steelhead brood stock to replace the current Eel River origin brood stock.

Hatchery practices as well as spatial and temporal overlaps of habitat use and spawning activity between spring- and fall-run fish have led to the hybridization and homogenization of some subpopulations (CDFG 1998). As early as the 1960s, Slater (1963) observed that early fall- and spring-run Chinook salmon were competing for spawning sites in the Sacramento River below Keswick Dam, and speculated that the two runs may have hybridized. The FRH spring-run Chinook salmon have been documented as straying throughout the Central Valley for many years (CDFG 1998), and in many cases have been recovered from the spawning grounds of fall-run Chinook salmon, an indication that FRH spring-run Chinook salmon may exhibit fall-run life history characteristics. Although the degree of hybridization has not been comprehensively determined, it is clear that the populations of spring-run Chinook salmon spawning in the Feather River and counted at RBDD contain hybridized fish.

The management of hatcheries, such as Nimbus Hatchery and FRH, can directly impact spring-run Chinook salmon and steelhead populations by oversaturating the natural carrying capacity of the limited habitat available below dams. In the case of the Feather River, significant redd superimposition occurs in-river due to hatchery overproduction and the inability to physically separate spring- and fall-run Chinook salmon adults. This concurrent spawning has led to hybridization between the spring- and fall-run Chinook salmon in the Feather River. At Nimbus Hatchery, operating Folsom Dam to meet temperature requirements for returning hatchery fall-run Chinook salmon often limits the amount if water available for steelhead spawning and rearing the rest of the year.

The increase in Central Valley hatchery production has reversed the composition of the steelhead population, from 88 percent naturally-produced fish in the 1950s (McEwan 2001) to an estimated 23 to 37 percent naturally-produced fish currently (Nobriga and Cadrett 2001). The increase in hatchery steelhead production proportionate to the wild population has reduced the viability of the wild steelhead populations, increased the use of out-of-basin stocks for hatchery production, and increased straying (NMFS and CDFG 2001). Thus, the ability of natural populations to successfully reproduce and continue their genetic integrity likely has been diminished.

The relatively low number of spawners needed to sustain a hatchery population can result in high harvest-to-escapements ratios in waters where fishing regulations are set according to hatchery population. This can lead to over-exploitation and reduction in the size of wild populations existing in the same system as hatchery populations due to incidental bycatch (McEwan 2001).

Hatcheries also can have some positive effects on salmonid populations. Artificial propagation has been shown to be effective in bolstering the numbers of naturally spawning fish in the short term under specific scenarios. Artificial propagation programs can also aid in conserving genetic resources and guarding against catastrophic loss of naturally spawned populations at critically low abundance levels, as was the case with the Sacramento River winter-run Chinook salmon population during the 1990s. However, relative abundance is only one component of a viable salmonid population.

7. <u>Over Utilization</u>

a. ***Ocean Commercial and Sport Harvest – Chinook Salmon and Steelhead***

Extensive ocean recreational and commercial troll fisheries for Chinook salmon exist along the Northern and Central California coast, and an inland recreational fishery exists in the Central Valley for Chinook salmon and steelhead. Ocean harvest of Central Valley Chinook salmon is estimated using an abundance index, called the Central Valley Index (CVI) harvest index. The CVI is the sum of the ocean fishery Chinook salmon harvested south of Point Arena (where 85 percent of Central Valley Chinook salmon are caught), plus the Central Valley adult Chinook salmon escapement.. The CVI harvest index is the ocean harvest landed south of Point Arena divided by the CVI. CWT returns indicate that Sacramento River salmon congregate off the California coast between Point Arena and Morro Bay.

Since 1970, the CVI harvest index for Sacramento River winter-run Chinook salmon generally has ranged between 0.50 and 0.80. In 1990, when ocean harvest of winter-run Chinook salmon was first evaluated by NMFS and the Pacific Fisheries Management Council (PFMC), the CVI harvest index was near the highest recorded level at 0.79. NMFS determined in a 1991 biological opinion that continuance of the 1990 ocean harvest rate would not prevent the recovery of Sacramento River winter-run Chinook salmon. In addition, the final rule designating winter-run Chinook salmon critical habitat (June 16, 1993, 58 FR 33212) stated that commercial and recreational fishing do not appear to be significant factors for the decline of the species. Through the early 1990s, the ocean harvest index was below the 1990 level (*i.e.*, 0.71 in 1991 and 1992, 0.72 in 1993, 0.74 in 1994, 0.78 in 1995, and 0.64 in 1996). In 1996 and 1997, NMFS issued a biological opinion which concluded that incidental ocean harvest of Sacramento River winter-run Chinook salmon represented a significant source of mortality to the endangered population, even though ocean harvest was not a key factor leading to the decline of the population. As a result of these opinions, measures were developed and implemented by the PFMC, NMFS, and CDFG to reduce ocean harvest by approximately 50 percent. In 2001 the CVI dropped to 0.27, most likely due to the reduction in harvest and the higher abundance of other salmonids originating from the Central Valley (Good *et al.* 2005).

Ocean fisheries have affected the age structure of Central Valley spring-run Chinook salmon through targeting large fish for many years and reducing the numbers of 4- and 5-year-old fish (CDFG 1998). Winter-run spawners have also been affected by ocean fisheries, as most spawners return as 3-year olds. As a result of very low returns of fall-run Chinook salmon to the Central Valley in 2007, there was a complete closure of commercial and recreational ocean

Chinook salmon fishery in 2008. As a result, there will likely be more 4- and 5-year old winter-run and spring-run returning to spawn in 2009. Ocean harvest rates of Central Valley spring-run Chinook salmon are thought to be a function of the CVI (Good *et al.* 2005). Harvest rates of Central Valley spring-run Chinook salmon ranged from 0.55 to nearly 0.80 between 1970 and 1995 when harvest rates were adjusted for the protection of Sacramento River winter-run Chinook salmon. The drop in the CVI in 2001 as a result of high fall-run escapement to 0.27 also reduced harvest of Central Valley spring-run Chinook salmon. There is essentially no ocean harvest of steelhead.

b. ***Inland Sport Harvest –Chinook Salmon and Steelhead***

Historically in California, almost half of the river sport fishing effort was in the Sacramento-San Joaquin River system, particularly upstream from the city of Sacramento (Emmett *et al.* 1991). Since 1987, the Fish and Game Commission has adopted increasingly stringent regulations to reduce and virtually eliminate the in-river sport fishery for Sacramento River winter-run Chinook salmon. Present regulations include a year-round closure to Chinook salmon fishing between Keswick Dam and the Deschutes Road Bridge and a rolling closure to Chinook salmon fishing on the Sacramento River between the Deschutes River Bridge and the Carquinez Bridge. The rolling closure spans the months that migrating adult Sacramento River winter-run Chinook salmon are ascending the Sacramento River to their spawning grounds. These closures have virtually eliminated impacts on Sacramento River winter-run Chinook salmon caused by recreational angling in freshwater. In 1992, the California Fish and Game Commission adopted gear restrictions (all hooks must be barbless and a maximum of 5.7 cm in length) to minimize hooking injury and mortality of winter-run Chinook salmon caused by trout anglers. That same year, the Commission also adopted regulations which prohibited any salmon from being removed from the water to further reduce the potential for injury and mortality.

In-river recreational fisheries historically have taken Central Valley spring-run Chinook salmon throughout the species' range. During the summer, holding adult Central Valley spring-run Chinook salmon are easily targeted by anglers when they congregate in large pools. Poaching also occurs at fish ladders, and other areas where adults congregate; however, the significance of poaching on the adult population is unknown. Specific regulations for the protection of Central Valley spring-run Chinook salmon in Mill, Deer, Butte, and Big Chico Creeks and the Yuba River have been added to the existing CDFG regulations. The current regulations, including those developed for Sacramento River winter-run Chinook salmon provide some level of protection for spring-run fish (CDFG 1998).

There is little information on steelhead harvest rates in California. Hallock *et al.* (1961) estimated that harvest rates for Sacramento River steelhead from the 1953-1954 through 1958-1959 seasons ranged from 25.1 percent to 45.6 percent assuming a 20 percent non-return rate of tags. The average annual harvest rate of adult steelhead above RBDD for the 3-year period from 1991-1992 through 1993-1994 was 16 percent (McEwan and Jackson 1996). Since 1998, all hatchery steelhead have been marked with an adipose fin clip allowing anglers to distinguish hatchery and wild steelhead. Current regulations restrict anglers from keeping unmarked steelhead in Central Valley streams. Overall, this regulation has greatly increased protection of naturally produced adult steelhead; however, the total number of Central Valley steelhead contacted might be a significant fraction of basin-wide escapement, and even low catch-and-release mortality may pose a problem for wild populations (Good *et al.* 2005).

c. ***Green Sturgeon***

Commercial harvest of white sturgeon results in the incidental bycatch of green sturgeon primarily along the Oregon and Washington coasts and within their coastal estuaries. Oregon and Washington have recently prohibited the retention of green sturgeon in their waters for commercial and recreational fisheries. Adams *et al.* (2002) reported harvest of green sturgeon from California, Oregon, and Washington between 1985 and 2001. Total captures of green sturgeon in the Columbia River Estuary by commercial means ranged from 240 fish per year to 6,000. Catches in Willapa Bay and Grays Harbor by commercial means combined ranged from 9 fish to 2,494 fish per year. Emmett *et al.* (1991) indicated that averages of 4.7 to 15.9 tons of green sturgeon were landed annually in Grays Harbor and Willapa Bay respectively. Overall, captures appeared to be dropping through the years; however, this could be related to changing fishing regulations. Adams *et al.* (2002) also reported sport fishing captures in California, Oregon, and Washington. Within the San Francisco Estuary, green sturgeon are captured by sport fisherman targeting the more desirable white sturgeon, particularly in San Pablo and Suisun bays (Emmett *et al.* 1991). Sport fishing in the Columbia River, Willapa Bay, and Grays Harbor captured from 22 to 553 fish per year between 1985 and 2001. Again, it appears sport fishing captures are dropping through time; however, it is not known if this is a result of abundance, changed fishing regulations, or other factors. Based on new research by Israel (2006a) and past tagged fish returns reported by CDFG (2002), a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as much as 80 percent in the Columbia River) may be Southern DPS North American green sturgeon. This indicates a potential threat to the Southern DPS North American green sturgeon population. Beamesderfer *et al.* (2007) estimated that green sturgeon will be vulnerable to slot limits (outside of California) for approximately 14 years of their life span. Fishing gear mortality presents an additional risk to the long-lived sturgeon species such as the green sturgeon (Boreman 1997). Although sturgeon are relatively hardy and generally survive being hooked, their long life makes them vulnerable to repeated hooking encounters, which leads to an overall significant hooking mortality rate over their lifetime. An adult green sturgeon may not become sexually mature until they are 13 to 18 years of age for males (152-185cm), and 16 to 27 years of age for females (165-202 cm, Van Eenennaam 2006). Even though slot limits "protect" a significant proportion of the life history of green sturgeon from harvest, they do not protect them from fishing pressure.

Green sturgeon are caught incidentally by sport fisherman targeting the more highly desired white sturgeon within the Delta waterways and the Sacramento River. New regulations which went into effect in March 2007, reduced the slot limit of sturgeon from 72 inches to 66 inches, and limit the retention of white sturgeon to one fish per day with a total of 3 fish retained per year. In addition, a non-transferable sturgeon punch card with tags must be obtained by each angler fishing for sturgeon. All sturgeon caught must be recorded on the card, including those released. All green sturgeon must be released unharmed and recorded on the sturgeon punch card by the angler.

Poaching rates of green sturgeon in the Central Valley are unknown; however, catches of sturgeon occur during all years, especially during wet years. Unfortunately, there is no catch, effort, and stock size data for this fishery which precludes making exploitation estimates (USFWS 1995a). Areas just downstream of Thermalito Afterbay outlet and Cox's Spillway, and several barriers impeding migration on the Feather River may be areas of high adult mortality from increased fishing effort and poaching. The small population of sturgeon inhabiting the San Joaquin River (believed to be currently comprised of only white sturgeon) experiences heavy fishing pressure, particularly regarding illegal snagging and it may be more than the population can support (USFWS 1995a).

8. Disease and Predation

Infectious disease is one of many factors that influence adult and juvenile salmonid survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (NMFS 1996a, 1996b, 1998a). Specific diseases such as bacterial kidney disease, *Ceratomyxosis shasta* (C-shasta), columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect steelhead and Chinook salmon (NMFS 1996a, 1996b, 1998a). Very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases; however, studies have shown that wild fish tend to be less susceptible to pathogens than are hatchery-reared fish. Nevertheless, wild salmonids may contract diseases that are spread through the water column (*i.e.*, waterborne pathogens) as well as through interbreeding with infected hatchery fish. The stress of being released into the wild from a controlled hatchery environment frequently causes latent infections to convert into a more pathological state, and increases the potential of transmission from hatchery reared fish to wild stocks within the same waters.

Accelerated predation also may be a factor in the decline of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon, and to a lesser degree Central Valley steelhead. Human-induced habitat changes such as alteration of natural flow regimes and installation of bank revetment and structures such as dams, bridges, water diversions, piers, and wharves often provide conditions that both disorient juvenile salmonids and attract predators (Stevens 1961, Decato 1978, Vogel *et al.* 1988, Garcia 1989).

On the mainstem Sacramento River, high rates of predation are known to occur at the RBDD, Anderson-Cottonwood Irrigation District's (ACID) diversion dam, GCID's diversion facility, areas where rock revetment has replaced natural river bank vegetation, and at South Delta water diversion structures (*e.g.*, Clifton Court Forebay; CDFG 1998). Predation at RBDD on juvenile winter-run Chinook salmon is believed to be higher than normal due to flow dynamics associated with the operation of this structure. Due to their small size, early emigrating winter-run Chinook salmon may be very susceptible to predation in Lake Red Bluff when the RBDD gates remain closed in summer and early fall. In passing the dam, juveniles are subject to conditions which greatly disorient them, making them highly susceptible to predation by fish or birds. Sacramento pikeminnow (*Ptychocheilus grandis*) and striped bass congregate below the dam and prey on juvenile salmon in the tail waters. The Sacramento pikeminnow is a species native to the Sacramento River basin and has co-evolved with the anadromous salmonids in this system. However, rearing conditions in the Sacramento River today (*e.g.*, warm water, low-irregular flow, standing water, and water diversions) compared to its natural state and function decades ago in the pre-dam era, are more conducive to warm water species such as Sacramento pikeminnow and striped bass than to native salmonids. Tucker *et al.* (1998) reported that predation during the summer months by Sacramento pikeminnow on juvenile salmonids increased to 66 percent of the total weight of stomach contents in the predatory pikeminnow. Striped bass showed a strong preference for juvenile salmonids as prey during this study. This research also indicated that the percent frequency of occurrence for juvenile salmonids nearly equaled other fish species in the stomach contents of the predatory fish. Tucker *et al.* (2003) showed the temporal distribution for these two predators in the RBDD area were directly related to RBDD operations (predators congregated when the dam gates were in, and dispersed when the gates were removed).

USFWS found that more predatory fish were found at rock revetment bank protection sites between Chico Landing and Red Bluff than at sites with naturally eroding banks (Michny and Hampton 1984). From October 1976 to November 1993, CDFG conducted 10 mark/recapture studies at the SWP's Clifton Court Forebay to estimate pre-screen losses using hatchery-reared juvenile Chinook salmon. Pre-screen losses ranged from 69 percent to 99 percent. Predation by striped bass is thought to be the primary cause of the loss (Gingras 1997).

Predation on juvenile salmonids has increased as a result of water development activities which have created ideal habitats for predators and non-native invasive species (NIS). Turbulent conditions near dam bypasses, turbine outfalls, water conveyances, and spillways disorient juvenile salmonid migrants and increase their predator avoidance response time, thus improving predator success. Increased exposure to predators has also resulted from reduced water flow through reservoirs; a condition which has increased juvenile travel time. Other locations in the Central Valley where predation is of concern include flood bypasses, post-release sites for salmonids salvaged at the CVP and SWP Fish Facilities, and the SMSCG. Predation on salmon by striped bass and pikeminnow at salvage release sites in the Delta and lower Sacramento River has been documented (Orsi 1967, Pickard *et al.* 1982); however, accurate predation rates at these sites are difficult to determine. CDFG conducted predation studies from 1987 to 1993 at the SMSCG to determine if the structure attracts and concentrates predators. The dominant predator species at the SMSCG was striped bass, and the remains of juvenile Chinook salmon were identified in their stomach contents (Edwards *et al.* 1996, Tillman *et al.* 1996, NMFS 1997).

Avian predation on fish contributes to the loss of migrating juvenile salmonids by constraining natural and artificial production. Fish-eating birds that occur in the California Central Valley include great blue herons (*Ardea herodias*), gulls (*Larus spp.*), osprey (*Pandion haliaetus*), common mergansers (*Mergus merganser*), American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Phalacrocorax spp.*), Caspian terns (*Sterna caspia*), belted kingfishers (*Ceryle alcyon*), black-crowned night herons (*Nycticorax nycticorax*), Forster's terns (*Sterna forsteri*), hooded mergansers (*Lophodytes cucullatus*), and bald eagles (*Haliaeetus leucocephalus*) (Stephenson and Fast 2005). These birds have high metabolic rates and require large quantities of food relative to their body size.

Mammals can also be an important source of predation on salmonids within the California Central Valley. Predators such as river otters (*Lutra canadensis*), raccoons (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and western spotted skunk (*Spilogale gracilis*) are common. Other mammals that take salmonid include: badger (*Taxidea taxus*), bobcat (*Linx rufis*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), mink (*Mustela vison*), mountain lion (*Felis concolor*), red fox (*Vulpes vulpes*), and ringtail (*Bassariscus astutus*). These animals, especially river otters, are capable of removing large numbers of salmon and trout from the aquatic habitat (Dolloff 1993). Mammals have the potential to consume large numbers of salmonids, but generally scavenge post-spawned salmon. In the marine environment, pinnipeds, including harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and Steller's sea lions (*Eumetopia jubatus*) are the primary marine mammals preying on salmonids (Spence *et al.* 1996). Pacific striped dolphin (*Lagenorhynchus obliquidens*) and killer whale (*Orcinus orca*) can also prey on adult salmonids in the nearshore marine environment, and at times become locally important. Although harbor seal and sea lion predation primarily is confined to the marine and estuarine environments, they are known to travel well into freshwater after migrating fish and have frequently been encountered in the Delta and the lower portions of the Sacramento and San Joaquin Rivers. All of these predators are opportunists, searching out locations where juveniles and adults are most vulnerable, such as the large water diversions in the South Delta.

9. Environmental Variation

Natural changes in the freshwater and marine environments play a major role in salmonid abundance. Recent evidence suggests that marine survival among salmonids fluctuates in response to 20- to 30-year cycles of climatic conditions and ocean productivity (Hare *et al.* 1999, Mantua and Hare 2002). This phenomenon has been referred to as the Pacific Decadal Oscillation. In addition, large-scale climatic regime shifts, such as the El Niño condition, appear to change productivity levels over large expanses of the Pacific Ocean. A further confounding effect is the fluctuation between drought and wet conditions in the basins of the American west. During the first part of the 1990s, much of the Pacific Coast was subject to a series of very dry years, which reduced inflows to watersheds up and down the west coast.

"El Niño" is an environmental condition often cited as a cause for the decline of West Coast salmonids (NMFS 1996b). El Niño is an unusual warming of the Pacific Ocean off South America and is caused by atmospheric changes in the tropical Pacific Ocean (Southern Oscillation-ENSO) resulting in reductions or reversals of the normal trade wind circulation patterns. The El Niño ocean conditions are characterized by anomalous warm sea surface temperatures and changes to coastal currents and upwelling patterns. Principal ecosystem alterations include decreased primary and secondary productivity in affected regions and changes in prey and predator species distributions. Cold-water species are displaced towards higher latitudes or move into deeper, cooler water, and their habitat niches occupied by species tolerant of warmer water that move upwards from the lower latitudes with the warm water tongue.

A key factor affecting many West Coast stocks has been a general 30-year decline in ocean productivity. The mechanism whereby stocks are affected is not well understood, partially because the pattern of response to these changing ocean conditions has differed among stocks, presumably due to differences in their ocean timing and distribution. It is presumed that survival in the ocean is driven largely by events occurring between ocean entry and recruitment to a sub-adult life stage.

10. Ecosystem Restoration

a. *California Bay-Delta Authority (CBDA)*

Two programs included under CBDA; the Ecosystem Restoration Program (ERP) and the EWA, were created to improve conditions for fish, including listed salmonids, in the Central Valley (CALFED 2000). Restoration actions implemented by the ERP include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors affecting listed salmonids and emphasis has been placed in tributary drainages with high potential for steelhead and spring-run Chinook salmon production. Additional ongoing actions include new efforts to enhance fisheries monitoring and directly support salmonid production through hatchery releases. Recent habitat restoration initiatives sponsored and funded primarily by the CBDA-ERP Program have resulted in plans to restore ecological function to 9,543 acres of shallow-water tidal and marsh habitats within the Delta. Restoration of these areas primarily involves flooding lands previously used for agriculture, thereby creating additional rearing habitat for juvenile salmonids. Similar habitat restoration is imminent adjacent to Suisun Marsh (*i.e.*, at the confluence of Montezuma Slough and the Sacramento River) as part of the Montezuma Wetlands project, which is intended to provide for commercial disposal of material dredged from San Francisco Bay in conjunction with tidal wetland restoration.

A sub-program of the ERP called the Environmental Water Program (EWP) has been established to support ERP projects through enhancement of instream flows that are biologically and ecologically significant in anadromous reaches of priority streams controlled by dams. This program is in the development stage and the benefits to listed salmonids are not yet clear. Clear Creek is one of five priority watersheds in the Central Valley that has been targeted for action during Phase I of the EWP.

The EWA is designed to provide water at critical times to meet ESA requirements and incidental take limits without water supply impacts to other users, particularly South of Delta water users. In early 2001, the EWA released 290 thousand acre feet of water from San Luis Reservoir at key times to offset reductions in South Delta pumping implemented to protect winter-run Chinook salmon, delta smelt, and splittail. However, the benefit derived by this action to winter-run Chinook salmon in terms of number of fish saved was very small. The anticipated benefits to other Delta fisheries from the use of the EWA water are much higher than those benefits ascribed to listed salmonids by the EWA release.

b. *Central Valley Project Improvement Act*

The CVPIA, implemented in 1992, requires that fish and wildlife get equal consideration with other demands for water allocations derived from the CVP. From this act arose several programs that have benefited listed salmonids: the Anadromous Fish Restoration Program (AFRP), the Anadromous Fish Screen Program (AFSP), and the Water Acquisition Program (WAP). The AFRP is engaged in monitoring, education, and restoration projects geared toward recovery of all anadromous fish species residing in the Central Valley. Restoration projects funded through the AFRP include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The AFSP combines Federal funding with State and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the WAP is to acquire water supplies to meet the habitat restoration and enhancement goals of the CVPIA and to improve the DOI's ability to meet regulatory water quality requirements. Water has been used successfully to improve fish habitat for spring-run Chinook salmon and steelhead by maintaining or increasing instream flows in Butte and Mill Creeks and the San Joaquin River at critical times.

c. *Iron Mountain Mine Remediation*

Environmental Protection Agency's Iron Mountain Mine remediation involves the removal of toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s (see Reclamation 2004 Appendix J). Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows in order to dilute heavy metal contaminants being spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

d. *State Water Project Delta Pumping Plant Fish Protection Agreement (Four-Pumps Agreement)*

The Four Pumps Agreement Program has approved about $49 million for projects that benefit salmon and steelhead production in the Sacramento-San Joaquin basins and Delta since the agreement inception in 1986. Four Pumps projects that benefit spring-run Chinook salmon and steelhead include water exchange programs on Mill and Deer Creeks; enhanced law enforcement efforts from San Francisco Bay upstream to the Sacramento and San Joaquin Rivers and their tributaries; design and construction of fish screens and ladders on Butte Creek; and screening of diversions in Suisun Marsh and San Joaquin tributaries. Predator habitat isolation and removal, and spawning habitat enhancement projects on the San Joaquin tributaries benefit steelhead (see Reclamation 2004 Chapter 15).

11. Non-Native Invasive Species

As currently seen in the San Francisco estuary, NIS can alter the natural food webs that existed prior to their introduction. Perhaps the most significant example is illustrated by the Asiatic freshwater clams *Corbicula fluminea* and *Potamocorbula amurensis*. The arrival of these clams in the estuary disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to the highly efficient filter feeding of the introduced clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the population levels of zooplankton that feed upon them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco estuary which feed either upon the zooplankton directly or their mature forms. This lack of forage base can adversely impact the health and physiological condition of these salmonids as they emigrate through the Delta region to the Pacific Ocean.

Attempts to control the NIS also can adversely impact the health and well-being of salmonids within the affected water systems. For example, the control programs for the invasive water hyacinth and *Egeria densa* plants in the Delta must balance the toxicity of the herbicides applied to control the plants to the probability of exposure to listed salmonids during herbicide application. In addition, the control of the nuisance plants have certain physical parameters that must be accounted for in the treatment protocols, particularly the decrease in DO resulting from the decomposing vegetable matter left by plants that have died.

12. Summary

For Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead, the construction of high dams for hydropower, flood control, and water supply resulted in the loss of vast amounts of upstream habitat (*i.e.*, approximately 80 percent, or a minimum linear estimate of over 1,000 stream miles), and often resulted in precipitous declines in affected salmonid populations. For example, the completion of Friant Dam in 1947 has been linked with the extirpation of spring-run Chinook salmon in the San Joaquin River upstream of the Merced River within just a few years. The reduced populations that remain below Central Valley dams are forced to spawn in lower elevation tailwater habitats of the mainstem rivers and tributaries that were previously not used for this purpose. This habitat is entirely dependent on managing reservoir releases to maintain cool water temperatures suitable for spawning, and/or rearing of salmonids. This requirement has been difficult to achieve in all water year types and for all life stages of affected salmonid species. Steelhead, in particular, seem to require the qualities of small tributary habitat similar to what they historically used for spawning; habitat that is largely unavailable to them under the current water management scenario. All salmonid species considered in this consultation have been adversely affected by the production of hatchery fish associated with the mitigation for the habitat lost to dam construction (*e.g.*, from genetic impacts, increased competition, exposure to novel diseases, *etc.*).

Land-use activities such as road construction, urban development, logging, mining, agriculture, and recreation are pervasive and have significantly altered fish habitat quantity and quality for Chinook salmon and steelhead through alteration of streambank and channel morphology; alteration of ambient water temperatures; degradation of water quality; elimination of spawning and rearing habitat; fragmentation of available habitats; elimination of downstream recruitment of LWD; and removal of riparian vegetation resulting in increased streambank erosion. Human-induced habitat changes, such as: alteration of natural flow regimes; installation of bank revetment; and building structures such as dams, bridges, water diversions, piers, and wharves, often provide conditions that both disorient juvenile salmonids and attract predators. Harvest activities, ocean productivity, and drought conditions provide added stressors to listed salmonid populations. In contrast, various ecosystem restoration activities have contributed to improved conditions for listed salmonids (*e.g.*, various fish screens). However, some important restoration activities (*e.g.*, Battle Creek Restoration Project) have not yet been implemented and benefits to listed salmonids from the EWA have been less than anticipated.

Similar to the listed salmonids, the Southern DPS of North American green sturgeon have been negatively impacted by hydroelectric and water storage operations in the Central Valley which ultimately affect the hydrology and accesibility of Central Valley rivers and streams to anadromous fish. Anthropogenic manipulations of the aquatic habitat, such as dredging, bank stabilization, and waste water discharges have also degraded the quality of the Central Valley's waterways for green sturgeon.

F. Existing Monitoring Programs

Salmonid-focused monitoring efforts are taking place throughout the Sacramento and San Joaquin River basins, and the Suisun Marsh. Many of these programs incidentally gather information on steelhead but a focused, comprehensive steelhead monitoring program has not been funded or implemented in the Central Valley. The existing salmonid monitoring efforts are summarized in Table 10 (Appendix A) by geographic area and target species. Information for this summary was derived from a variety of sources:

- IEP's (1999) Steelhead Project Work Team report on monitoring, assessment, and research on steelhead: status of knowledge, review of existing programs, and assessment of needs;
- CDFG Plan;
- U.S. Forest Service Sierra Nevada Framework monitoring plan;
- ESA section 10 and section 4(d) scientific research permit applications;
- Trinity River Restoration Program biological monitoring; and
- Suisun Marsh Monitoring Program.

Studies focused on the life history of green sturgeon are currently being implemented by researchers at academic institutions such as University of California, Davis. Future plans include radio-telemetry studies to track the movements of green sturgeon within the Delta and Sacramento River systems. Additional studies concerning the basic biology and physiology of green sturgeon are also being conducted to better understand the fish's niche in the aquatic system.

IV. ENVIRONMENTAL BASELINE

The environmental baseline "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR §402.02).

A. Status of the Species and Critical Habitat in the Action Area

1. <u>Status of the Species within the Action Area</u>

The action area functions primarily as a migratory corridor for adult and juvenile Central Valley steelhead. All adult Central Valley steelhead originating in the San Joaquin River watershed will have to migrate through the action area in order to reach their spawning grounds and to return to the ocean following spawning. Likewise, all Central Valley steelhead smolts originating in the San Joaquin River watershed will also have to pass through the action area during their emigration to the ocean. The waterways in the action area also are expected to provide some rearing benefit to emigrating steelhead smolts as they move through the action area. The action area also provides some use as a migratory corridor and rearing habitat for juveniles of the Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon ESUs that are drawn into the South Delta by the actions of the CVP and SWP water diversion facilities. The action area also functions as migratory, holding and rearing habitat for adult and juvenile Southern DPS of North American green sturgeon.

a. *Sacramento River Winter-Run Chinook Salmon*

The temporal occurrence of Sacramento River winter-run Chinook salmon smolts and juveniles in the action area are best described by the salvage records of the CVP and SWP fish handling facilities. Based on salvage records covering the last 8 years at the CVP and SWP, Sacramento River winter-run Chinook salmon are typically present in the South Delta action area starting in December. Their presence peaks in March and then rapidly declines from April through June. Nearly 50 percent of the average annual salvage of Sacramento River winter-run Chinook salmon juveniles occurs in March (48.8 percent). Salvage in April accounts for only 2.8 percent of the average annual salvage and falls to less than 1 percent for May and June combined (see Appendix A, Table 11.). The presence of juvenile Sacramento River winter-run Chinook salmon in the South Delta is a function of river flows on the Sacramento River, where the fish are spawned, and the demands for water diverted by the SWP and CVP facilities. When conditions on the Sacramento River are conducive to stimulating outmigrations of juvenile Sacramento River winter-run Chinook salmon, the draw of the CVP and SWP pumping facilities pulls a portion of these emigrating fish through one of the four access points on the Sacramento River (Georgiana Slough, the Delta Cross Channel, Three Mile Slough, and the San Joaquin River via

Broad Slough) into the channels of the South Delta. The combination of pumping rates and tidal flows moves these fish towards the southwestern corner of the Delta and into the action area. When the combination of pumping rates and fish movements are high, significant numbers of juvenile Sacramento River winter-run Chinook salmon are drawn into the South Delta.

b. *Central Valley Spring-Run Chinook salmon*

Like the Sacramento River winter-run Chinook salmon, the presence of juvenile Central Valley spring-run Chinook salmon in the action area is under the influence of the CVP and SWP water diversions and the flows on the Sacramento River and its tributary watersheds. Currently, all known populations of Central Valley spring-run Chinook salmon inhabit the Sacramento River watershed. The San Joaquin River watershed populations have been extirpated, with the last known runs on the San Joaquin River being extirpated in the late 1940s and early 1950s by the construction of Friant Dam and the opening of the Kern-Friant irrigation canal.

Juvenile Central Valley spring-run Chinook salmon first begin to appear in the action area in January. A significant presence of fish does not occur until March (20.1 percent of average annual salvage) and peaks in April (66.8 percent of average annual salvage) (see Appendix A Table 11). By May, the salvage of Central Valley spring-run Chinook salmon juveniles declines sharply (11.5 percent of average annual salvage) and essentially ends by the end of June (1.3 percent of average annual salvage).

c. *Central Valley Steelhead*

The Central Valley steelhead DPS occurs in both the Sacramento River and the San Joaquin River watersheds. However the spawning population of fish is much greater in the Sacramento River watershed and accounts for nearly all of the DPS' population. Like Sacramento River Chinook salmon, Sacramento River steelhead can be drawn into the South Delta by the actions of the CVP and SWP water diversion facilities. Small, remnant populations of Central Valley steelhead are known to occur on the Stanislaus River and the Tuolumne River and their presence is assumed on the Merced River due to proximity, similar habitats, and historical presence. Central Valley steelhead smolts first start to appear in the action area in November based on the records from the CVP and SWP fish salvage facilities (see Appendix A Table 11). Their presence increases through December and January (23.4 percent of average annual salvage) and peaks in February (34.6 percent) and March (31.6 percent) before rapidly declining in April (7.8 percent). By June, the emigration has essentially ended, with only a small number of fish being salvaged through the summer at the CVP and SWP. Kodiak trawls conducted by the USFWS and CDFG on the mainstem of the San Joaquin River just above the HOR during the VAMP experimental period routinely catch low numbers of outmigrating steelhead smolts from the San Joaquin Basin. Monitoring is less frequent prior to the VAMP, therefore emigrating steelhead smolts have a lower probability of being detected. The RST monitoring on the Stanislaus River at Caswell State Park and further upriver near the City of Oakdale indicate that smolt-sized fish start emigrating downriver in January and can continue through late May. Fry sized fish (30 to 50 mm) are captured at the Oakdale RST starting as early as April and continuing through June. Adult escapement numbers have been monitored for the past several years with the installation of an Alaskan style weir on the lower Stanislaus River near Riverbank. Typically, very few adult steelhead have been observed moving upstream past the weir. However, in 2006 to 2007, the weir was left in through the winter and spring and seven adult steelhead were counted moving upstream.

d. *Southern DPS of North American Green Sturgeon*

Juvenile green sturgeon from the Southern DPS are routinely collected at the SWP and CVP salvage facilities throughout the year. However, numbers are considerably lower than for other species of fish monitored at the facilities. Based on the salvage records from 1981 through 2007, green sturgeon may be present during any month of the year, and have been particularly prevalent during July and August (see Appendix B Figure 6). The sizes of these fish are less than 1 meter and average 330 mm with a range of 136 mm to 774 mm. The size range indicates that these are sub-adult fish rather than adult or larval/juvenile fish. It is believed that these sub-adult fish utilize the Delta for rearing for up to a period of approximately 3 years. The proximity of the CVP and SWP facilities to the action area would indicate that sub-adult green sturgeon have a strong potential to be present within the action area during the construction and operation of the temporary barriers, but that their population density would be low in these waters.

2. <u>Status of Critical Habitat Within the Action Area</u>

The action area is within the San Joaquin Delta subbasin (hydrologic unit [HU] # 5544) and is included in the critical habitat designated for Central Valley steelhead. The San Joaquin Delta HU is in the southwestern portion of the Central Valley steelhead DPS range and includes portions of the south and central Delta channel complex. The San Joaquin Delta HU encompasses approximately 628 square miles, with 455 miles of stream channels (at 1:100,000 hydrography). The critical habitat analytical review team (CHART) identified approximately 276 miles of occupied riverine/estuarine habitat in this hydrologic subunit area (HSA) and that it contained one or more PCEs for the Central Valley steelhead DPS (NMFS 2005b). The PCEs of steelhead habitat within the action area include freshwater rearing habitat, freshwater migration corridors, and estuarine areas. The features of the PCEs included in these different sites essential to the conservation of the Central Valley steelhead DPS include the following: sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions necessary for salmonid development and mobility, sufficient water quality, food and nutrients sources, natural cover and shelter, migration routes free from obstructions, no excessive predation, holding areas for juveniles and adults, and shallow water areas and wetlands. Habitat within the action area is primarily utilized for freshwater rearing and migration by Central Valley steelhead juveniles and smolts and for adult freshwater migration. No spawning of Central Valley steelhead occurs within the action area.

In regards to the proposed critical habitat for the Southern DPS of green sturgeon, the action area includes PCEs concerned with: adequate food resources for all life stages utilizing the Delta, water flows sufficient to allow adults, subadults, and juveniles to orient to flows for migration and normal behavioral responses, water quality sufficient to allow normal physiological and behavioral responses, provide for unobstructed migratory corridors for all life stages utilizing the Delta, provide a broad spectrum of water depths to satisfy the needs of the different life stages present in the estuary, and sediment with sufficiently low contaminant burdens to allow for normal physiological and behavioral responses to the environment.

The general condition and function of this habitat has already been described in the *Status of the Species and Critical Habitat* section of this biological opinion. The substantial degradation over time of several of the essential critical elements has diminished the function and condition of the freshwater rearing and migration habitats in the action area. It has only rudimentary functions compared to its historical status. The channels of the South Delta have been heavily riprapped with coarse stone slope protection on artificial levee banks and these channels have been straightened to enhance water conveyance through the system. The extensive riprapping and levee construction has precluded natural river channel migrations and the formation of riffle pool configurations in the Delta's channels. The natural floodplains have essentially been eliminated, and the once extensive wetlands and riparian zones have been cleared for farming. Little riparian vegetation remains in the South Delta, limited mainly to tules growing along the foot of artificial levee banks. Numerous artificial channels also have been created to bring water to irrigated lands that historically did not have access to the river channels (*i.e.*, Victoria Canal, Grant Line Canal, Fabian and Bell Canal, Woodward Cut, *etc.*). These artificial channels have disturbed the natural flow of water through the South Delta. As a byproduct of this intensive engineering of the Delta's hydrology, numerous irrigation diversions have been placed along the banks of the flood control levees to divert water from the area's waterways to the agricultural lands of the Delta's numerous "reclaimed" islands. Most of these diversions are not screened adequately to protect migrating fish from entrainment. Sections of the South Delta have been routinely dredged by DWR to provide adequate intake depth to these agricultural water diversions. Shallow water conditions created by the actions of the SWP enhance the probability of pump cavitation or loss of head on siphons. NMFS has issued a biological opinion that assesses the impacts DWR's South Delta Diversions Dredging and Modification Program (October 27, 2003; SWR-02-SA-6433:JSS). That biological opinion included NMFS' terms and conditions to avoid and minimize incidental take of listed species in the South Delta. That biological opinion expired at the end of 2008.

Water flow through the South Delta is highly manipulated to serve human purposes. Rainfall and snowmelt is captured by reservoirs in the upper watersheds, from which its release is dictated primarily by downstream human needs. The SWP and CVP pumps draw water towards the southwest corner of the Delta which creates a net upstream flow of water towards their intake points. Fish, and the forage base they depend upon for food, are drawn along with the current towards these diversion points. In addition to the altered flow patterns in the South Delta, numerous discharges of treated wastewater from sanitation wastewater treatment plants (*e.g.*, Cities of Tracy, Stockton, Manteca, Lathrop, Modesto, Turlock, Riverbank, Oakdale, Ripon, Mountain House, and the Town of Discovery Bay) and the untreated discharge of numerous agricultural wasteways are emptied into the waters of the San Joaquin River and the channels of the South Delta. This leads to cumulative additions to the system of thermal effluent loads as well as cumulative loads of potential contaminants (*i.e.*, selenium, boron, endocrine disruptors, pesticides, biostimulatory compounds, *etc.*).

The installation of the temporary rock barriers has been an ongoing action since 1991. Installation of the HOR fall barrier has occurred intermittently since the early 1960s to enhance water quality downstream in the Port of Stockton and the DWSC. These barriers have altered the hydrology of the South Delta each time they have been installed by redirecting flows and increasing water elevation behind the barriers.

Even though the habitat has been substantially altered and its quality diminished through years of human actions, its conservation value remains high for San Joaquin River basin steelhead. This segment of the Central Valley steelhead DPS must pass through the San Joaquin Delta HSA to reach their upstream spawning and freshwater rearing areas on the tributary watersheds. Therefore, it is of critical importance to the long-term viability of the San Joaquin River basin portion of the Central Valley steelhead DPS to maintain a functional migratory corridor and freshwater rearing habitat through the action area and the San Joaquin Delta HSA.

B. Factors Affecting the Species and Habitat in the Action Area

The action area encompasses a small portion of the area utilized by the Central Valley steelhead DPS as well as the Southern DPS of North American green sturgeon. Many of the range-wide factors affecting these two species are discussed in the *Status of the Species and Critical Habitat* section of this biological opinion, and are considered the same in the action area. This section will focus on the specific factors in the action area that are most relevant to the proposed TBP.

The magnitude and duration of peak flows during the winter and spring, which affects listed salmonids in the action area, are reduced by water impoundment in upstream reservoirs. Instream flows during the summer and early fall months have increased over historic levels for deliveries of municipal and agricultural water supplies. Overall, water management now reduces natural variability by creating more uniform flows year-round. Current flood control practices require peak flood discharges to be held back and released over a period of weeks to avoid overwhelming the flood control structures downstream of the reservoirs (*i.e.*, levees) and low lying terraces under cultivation (*i.e.*, orchards and row crops) in the natural floodplain along the basin tributaries. Consequently, managed flows in the mainstem of the river often truncate the peak of the flood hydrograph and extended the reservoir releases over a protracted period. These actions reduce or eliminate the scouring flows necessary to mobilize sediments and create natural riverine morphological features within the action area. Furthermore, the unimpeded river flow in the San Joaquin River basin is severely reduced by the combined storage capacity of the different reservoirs located throughout the basin's watershed. Very little of the natural hydrologic input to the basin is allowed to flow through the reservoirs to the valley floor sections of the tributaries leading to the Delta. Most is either stored or diverted for anthropogenic uses. Elevated flows on the valley floor are typically only seen in wet years or flood conditions, when the storage capacities of the numerous reservoirs are unable to contain all of the inflow from the watersheds above the reservoirs.

High water temperatures also limit habitat availability for listed salmonids in the San Joaquin River and the lower portions of the tributaries feeding into the mainstem of the river. High summer water temperatures in the lower San Joaquin River frequently exceed 72 ^{o}F, and create a thermal barrier to the migration of adult and juvenile salmonids (CDEC database).

Levee construction and bank protection have affected salmonid habitat availability and the processes that develop and maintain preferred habitat by reducing floodplain connectivity, changing riverbank substrate size, and decreasing riparian habitat and shaded riverine aquatic (SRA) cover. Such bank protection generally results in two levels of impacts to the environment: (1) site-level impacts which affect the basic physical habitat structure at individual bank protection sites; and (2) reach-level impacts which are the cumulative impacts to ecosystem functions and processes that accrue from multiple bank protection sites within a given river reach (USFWS 2000). Revetted embankments result in loss of sinuosity and braiding and reduce the amount of aquatic habitat. Impacts at the reach level result primarily from halting erosion and controlling riparian vegetation. Reach-level impacts which cause significant impacts to fish are reductions in new habitats of various kinds, changes to sediment and organic material storage and transport, reductions of lower food-chain production, and reduction in LWD.

The use of rock armoring limits recruitment of LWD (*i.e.*, from non-riprapped areas), and greatly reduces, if not eliminates, the retention of LWD once it enters the river channel. Riprapping creates a relatively clean, smooth surface which diminishes the ability of LWD to become securely snagged and anchored by sediment. LWD tends to become only temporarily snagged along riprap, and generally moves downstream with subsequent high flows. Habitat value and ecological functioning aspects are thus greatly reduced, because wood needs to remain in place for extended periods to generate maximum values to fish and wildlife (USFWS 2000). Recruitment of LWD is limited to any eventual, long-term tree mortality and whatever abrasion and breakage may occur during high flows (USFWS 2000). Juvenile salmonids are likely being impacted by reductions, fragmentation, and general lack of connectedness of remaining nearshore refuge areas.

PS and NPS of pollution resulting from agricultural discharge and urban and industrial development occur upstream of, and within the action area. The effects of these impacts are discussed in detail in the *Status of the Species and Critical Habitat* section. Environmental stresses as a result of low water quality can lower reproductive success and may account for low productivity rates in fish (*e.g.* green sturgeon, Klimley 2002). Organic contaminants from agricultural drain water, urban and agricultural runoff from storm events, and high trace element (*i.e.*, heavy metals) concentrations may deleteriously affect early life-stage survival of fish in the Central Valley watersheds (USFWS 1995b). Other impacts to adult migration present in the action area, such as migration barriers, water conveyance factors, water quality, NIS, *etc.*, are discussed in the *Status of Species and Critical Habitat* section.

V. EFFECTS OF THE ACTION

A. Approach to the Assessment

Pursuant to section 7(a)(2) of the ESA (16 U.S.C. §1536), Federal agencies are directed to ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. Regulations that implement section 7(b)(2) of the ESA require biological opinions to evaluate the direct and indirect effects of Federal actions and actions that are interrelated with or interdependent to the Federal action to determine if it would be reasonable to expect them to appreciably reduce listed species' likelihood of surviving and recovering in the wild by reducing their reproduction, numbers, or distribution (16 U.S.C. §1536; 50 CFR 402.02). Section 7 of the ESA and its implementing regulations also require biological opinions to determine if Federal actions would destroy or adversely modify the conservation value of critical habitat (16 U.S.C. §1536). This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat. NMFS will evaluate destruction or adverse modification of critical habitat by determining if the action reduces the value of critical habitat for the conservation of the species. This biological opinion assesses the effects of the proposed action on endangered Sacramento River winter-run Chinook salmon, threatened Central Valley spring-run Chinook salmon, threatened Central Valley steelhead, the threatened Southern DPS of North American green sturgeon, and designated critical habitat for Central Valley steelhead.

In the *Description of the Proposed Action* section of this biological opinion, NMFS provided an overview of the action. In the *Status of the Species* and *Environmental Baseline* sections of this biological opinion, NMFS provided an overview of the threatened and endangered species and critical habitat that are likely to be adversely affected by the activity under consultation.

NMFS generally approaches the "jeopardy" and critical habitat modification analyses in a series of steps. First, NMFS evaluates the available evidence to identify direct and indirect physical, chemical, and biotic effects of the proposed action on individual members of listed species or aspects of the species' environment (these effects include direct, physical harm or injury to individual members of a species; modifications to something in the species' environment - such as reducing a species' prey base, enhancing populations of predators, altering its spawning substrate, altering its ambient temperature regimes; or adding something novel to a species' environment - such as introducing exotic competitors or a sound). Once NMFS has identified the effects of the action, the available evidence is evaluated to identify a species' probable response (including behavioral responses) to those effects to determine if those effects could reasonably be expected to reduce a species' reproduction, numbers, or distribution (for example, by changing birth, death, immigration, or emigration rates; increasing the age at which individuals reach sexual maturity; decreasing the age at which individuals stop reproducing; and others). The available evidence is then used to determine if these reductions, if there are any, could reasonably be expected to appreciably reduce a species' likelihood of surviving and recovering in the wild.
To conduct this assessment, NMFS examined information from a variety of sources. Detailed background information on the status of these species and critical habitat has been published in a number of documents including peer reviewed scientific journals, primary reference materials, government and non-government reports, the BA for the TBP, and supplemental material provided by DWR in response to questions asked by NMFS.

B. Assessment

The NPB is a multi-stimulus fish barrier that combines LED strobe lights, an air bubble curtain, and sound generation at frequencies and levels that are repellent to fish. The NPB is intended to create a behavioral deterrent for juvenile salmon in the San Joaquin River, rather than a physical barrier as initially proposed under the TBP, to prevent entry to Old River. The sound system and strobe light flash rate can be tuned to known sensitivities of various fish species. Bowen *et al.* (2008) has shown that when the sound and strobe light flash rate were tuned according to Chinook salmon and delta smelt sensitivities, the barrier was effective as a deterrent for Chinook salmon smolts. Based on their laboratory research, Bowen *et al.* (2008), concluded that the sound is the actual deterrent, the bubbles contain the sound so that fish recognize the source, and the lights help identify the bubbles so that the source of the sound can be determined by the fish. Bowen *et al.* (2008) also indicate that Chinook salmon do respond to the NPB by choosing a pathway other than the one leading to the source of the sound. As such, it is expected that the NPB would deter Chinook salmon from entering Old River.

1. Construction Impacts

A full description of the barrier installation, operational schedule, and removal is given in *Section II (4)* of this biological opinion. Based on the salvage data from the CVP and SWP facilities from 1999 to the present available on Reclamation's Central Valley Operations web site (http://www. usbr.gov/mp/cvo/), NMFS expects individuals from the Sacramento River winter-run Chinook salmon ESU, Central Valley spring-run Chinook salmon ESU, Central Valley steelhead DPS, and North American green sturgeon, Southern DPS, are expected to be present in the South Delta during the proposed spring construction periods. NMFS estimates that approximately 3 percent of the annual Sacramento River winter-run Chinook salmon emigrants that are collected at the CVP and SWP facilities are collected during April. Likewise, the salvage data from the past 7 years indicates that approximately two thirds (66.8 percent) of the annual Central Valley spring-run Chinook salmon outmigration through the Delta occurs during April, as represented by the salvage data at the CVP and SWP fish collection facilities. Therefore, even though these two Chinook salmon runs do not originate in the San Joaquin River watershed, their presence at the SWP and CVP fish salvage facilities in the southwest corner of the Delta indicates that they are likely to be present in the western waterways of the South Delta during the TBP construction actions. The same data indicate that approximately 8 percent of the total annual Central Valley steelhead smolt outmigration takes place during April and thus also faces exposure to the barrier installation activities. It is unclear exactly what proportion of the total Central Valley steelhead DPS smolts outmigration is comprised of those smolts emigrating from the San Joaquin River watershed. Those smolts that do emigrate from the San Joaquin River watershed during the April (or later) time frame are likely to face at least one of the barriers during their migration through the Delta. Finally, low numbers of juvenile and sub adult green sturgeon from the Southern DPS are collected at the CVP and SWP fish collection facilities throughout the year, including the month of April. Much is unknown about how these young green sturgeon utilize the channels of the South Delta, including their distribution and range, their behavior, and their density. However, like the different salmonids, their presence at the fish collecting facilities indicates that they are present in the south western corner of the Delta and can be expected to occur in any of the adjoining waterways feeding into the region adjacent to the CVP and SWP intakes, including Old River, MR, GLC and Fabian – Bell Canal.

The construction of the barriers for the TBP requires the placement of rock and gravel into the channels of the South Delta during a time period when outmigrating Central Valley steelhead smolts are present in the San Joaquin River mainstem. Furthermore, due to the physical proximity of the three agricultural barriers (ORT, MR, GLC) to the intakes of the CVP and SWP, when juveniles from the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, Central Valley steelhead DPS and the Southern DPS of North American green sturgeon are present at the CVP/SWP diversions during the construction period, then these fish are assumed to be present in the waterways containing these three barriers. The placement of rock below the waterline will cause noise and physical disturbance that could displace juvenile and adult fish into adjacent habitats, or crush and injure or kill individuals. The impact of rock being placed in the river disrupts the river flow by producing surface water waves disturbing the water column; resulting in increased turbulence and turbidity. Migrating juveniles react to this situation by a startle response in which they are likely to suddenly disperse in random directions (Carlson *et al.* 2001). This displacement can lead them into predator habitat where they can be targeted, and injured and killed by opportunistic predators taking advantage of juvenile behavioural changes (see later discussion on predation). Carlson *et al.* (2001) observed this behaviour occurring in response to routine channel maintenance activities in the Columbia River. Some of the fish that did not immediately recover from the disorientation of turbidity and noise from channel dredges and pile driving swam directly into the point of contact with predators.

The construction of the rock barriers also is expected to generate underwater noise from both terrestrial and underwater sources, occasionally reaching intense levels. Heavy earthmoving equipment will be utilized on the banks of the rivers and levees to move the piles of rock and gravel needed for the construction of the barriers. These activities will generate sharp transient noises from metal components (buckets, scoops, etc.) striking rock that will propagate into the water column as coupled noise traveling through the underlying substrate. The process of dumping the rocky material into the water from front loaders, excavators, and dump trucks is expected to generate intense noise from the rocks striking each other as they fall and tumble into their final position. The effects resulting from the generation of intense sound within the water column can be extrapolated from reports on dredging and pile driving. Feist *et al.* (1992) found that noise from pile driving activities in Puget Sound affected the general behaviour of juvenile salmon by temporarily displacing them from the active construction areas. Nearly twice as many fish were observed at construction sites on non-pile driving days compared to days when pile driving occurred. However, on the waterways of the San Joaquin River and the South Delta, the channel widths (<100m) may not allow complete avoidance of the construction disturbances. A report by Burgess and Blackwell (2003) indicated that vibratory installation of a sheet pile wall in an upland position generated sound levels of approximately 140 dB (re: 1 μpascal [1μPa]) in the adjacent waterway at a distance of 200 feet, indicating that the noise was transmitted through the soil to the water column. Although NMFS was not able to find specific data or reports in the literature for similar construction activities, the level of noise generated in the proposed TBP is not expected to reach levels that will incur tissue injury (> 207 decibels peak; referenced to 1μPa), but is likely to create behavioral alterations in exposed fish (>150 decibels root mean square (dB_{rms}), re: 1μPa). The duration of the rock placement activity is not expected to occur for more than 2 weeks, and is likely to last only 1 week (*i.e.*, April 7 through April 15). NMFS will assess the 2 week duration of construction as a worst case scenario. Placement of the rock occurs only during daylight hours, and the repetitive frequency of the rocks being dumped is measured on the order of half a minute (excavator) to several minutes (dump trucks and front loaders) (J. Stuart, Biologist, NMFS 2005, personal observation). This reduces the risk of accumulated sound levels as experienced during pile driving activities that have a repetitive frequency measured on the order of a few seconds between strikes.

The placement of the large volumes of rock and gravel necessary to construct the barriers into the channels of the South Delta places migrating fish at risk of being crushed or injured by the falling rock. NMFS believes that due to the process of closing off the channel with the rock barriers, all sizes of fish (ranging from approximately 80 mm Chinook salmon smolts to 250 mm steelhead smolts) are at some risk of exposure to the construction activity. Typically, smaller fry-sized fish would have the highest risk potential due to their nearshore orientation and slower swimming speeds but this size class of fish is unlikely to be present in the construction area due to season and its location downstream of the natal reaches of steelhead and Chinook salmon. However, since the barriers progressively move across the width of the channel, even those larger smolt-sized fish migrating though the center of the channel, which are anticipated to be in the action area, would at some point be vulnerable to the rock placement process as they try to move through the construction area under the influence of the river's flow. NMFS could not find any scientific data to describe fish passage through a similar construction area, and thus must make its evaluation based on the conditions present at the different construction sites. NMFS believes that most migrating fish will pass through the barrier construction zones when terrestrial activity is low or absent, particularly as the barrier nears completion and the depth of the water across the top of the barrier crest becomes shallower. NMFS further believes that passage over the crest is more likely to occur under low light conditions, when construction activity should not be occurring. However, individual fish could decide to cross the alignment of the barrier at any time and thus face a higher level of risk.

Rock placement and positioning of associated structures, such as the barrier culverts, will disturb local soils and the underlying riverbed, resulting in increased erosion, siltation, and sedimentation. Highly elevated suspended sediments can adversely affect salmonids in the area by clogging sensitive gill structures (Nightingale and Simenstad 2001) but these effects are generally confined to turbidity levels in excess of 4,000 mg/L. Based on the best available information, NMFS does not anticipate that turbidity levels associated with the TBP will reach these deleterious levels. However, responses of salmonids to elevated levels of suspended sediments often fall into three major categories: physiological effects, behavioral effects, and habitat effects (Bash *et al.* 2001). The severity of the effect is a function of concentration and duration (Newcombe and MacDonald 1991, Newcombe and Jensen 1996) so that low concentrations and long exposure periods are frequently as deleterious as short exposures to high concentrations of suspended sediments. A review by Lloyd (1987) indicated that several behavioral characteristics of salmonids can be altered by even relatively small changes in turbidity (10 to 50 Nephelometric Turbidity Units [NTUs]). Salmonids exposed to slight to moderate increases in turbidity exhibited avoidance, loss of station in the stream, reduced feeding rates and reduced use of overhead cover. Short-term increases in turbidity and suspended sediment may disrupt feeding activities of fish or result in temporary displacement from preferred habitats. Numerous studies show that suspended sediment and turbidity levels moderately elevated above natural background values can result in non-lethal detrimental effects to salmonids. Suspended sediment affects salmonids by decreasing reproductive success, reducing feeding success and growth, causing avoidance of rearing habitats, and disrupting migration cues (Bash *et al.* 2001). Sigler *et al.* (1984 *in* Bjornn and Reiser 1991) found that prolonged turbidity between 25 and 50 NTUs reduced growth of juvenile coho salmon and steelhead. MacDonald *et al.* (1991) found that the ability of salmon to find and capture food is impaired at turbidities from 25 to 70 NTUs. Reaction distances of rainbow trout to prey were reduced with increases of turbidity of only 15 NTUs over an ambient level of 4 to 6 NTUs in experimental stream channels (Barret *et al.* 1992). Bisson and Bilby (1982) reported that juvenile coho salmon avoid turbidities exceeding 70 NTUs. Increased turbidity, used as an indicator of increased suspended sediments, also is correlated with a decline in primary productivity, a decline in the abundance of periphyton, and reductions in the abundance and diversity of invertebrate fauna in the affected area (Lloyd 1987, Newcombe and MacDonald 1991). Increased sediment delivery can also fill interstitial substrate spaces and reduce cover for juvenile fish (Platts *et. al.* 1979) and abundance and availability of aquatic invertebrates for food (Bjornn and Reiser 1991). NMFS expects turbidity to affect Chinook salmon and steelhead in much the same way that it affects the other salmonids used in these studies, because of similar physiological and life history requirements between species.

Resuspension of contaminated sediments is expected to have adverse effects upon salmonids or green sturgeon that encounter the sediment plume, even at low turbidity levels. Lipophilic compounds in the fine organic sediment, such as toxic PAHs, can be preferentially absorbed through the lipid membranes of the gill tissue, providing an avenue of exposure to salmonids or green sturgeon within the sediment plume (Newcombe and Jensen 1996). Similarly, charged particles such as metals (*e.g.*, copper), may interfere with ion exchange channels on sensitive membrane structures like gills or olfactory rosettes and increases in ammonia from the sediment may create acutely toxic conditions for salmonids or green sturgeon present in the channel margins.

Suspended sediment from the barrier construction activities would increase turbidity at the four barrier project sites and these plumes would continue down current from the installation site (all four barrier locations are under tidal influence and therefore have bidirectional water flow through the action area twice a day). Although Chinook salmon and steelhead are highly migratory and capable of moving freely throughout the action area, an increase in turbidity may injure fish by temporarily disrupting normal behaviors that are essential to growth and survival such as feeding, sheltering, and migrating. Injury is caused when disrupting these behaviors increases the likelihood that individual fish will face increased competition for food and space, and experience reduced growth rates or possibly weight loss. TBP-related turbidity increases may also affect the sheltering abilities of some fish and may decrease their likelihood of survival by increasing their susceptibility to predation.

Based on similar projects conducted by DWR and the Corps (*i.e.*, levee repair work and placement of rock riprap), construction activities are expected to result in periodic turbidity levels that ranged from 25 to 75 NTUs. These levels are capable of affecting normal feeding and sheltering behavior. Although levee protection work on the Sacramento River produced turbidity plumes that hugged the shoreline for several hundred feet downstream of the rock placement action, work on the TBP is expected to produce plumes that are more dispersed across the river channel. The river channels in the South Delta are narrower than the Sacramento River channel or its associated distributaries and have a strong tidal signal in the action area. The tidal signal causes the flow in the river channel to reverse itself twice a day, thus moving the sediment plume upstream and downstream on each tidal cycle with some degree of overlap. Furthermore, the barriers span the entire channel and are not just restricted to the channel edges. This allows sediment plumes to be present across the entire width of the channel at some point in the construction cycle. Eventually the gap between the two leading edges of the barrier is sufficiently narrow that the sediment plume will cover the entire width of the open channel in the construction zone. Once construction stops, water quality is expected to return to background levels within a few hours to days, depending on how high the percentage of fines were in the stockpiled barrier material. Adherence to erosion control measures and BMPs such as use of silt fences, straw bales, and straw wattles will minimize the amount of TBP-related sediment originating from the upland areas of the TBP and will minimize the potential for post-construction turbidity changes should precipitation events occur after the barrier construction. NMFS expects that most fish will actively avoid the elevated turbidity plumes if possible. For those fish that do not or cannot avoid the turbid water, exposure is expected to be brief (*i.e.*, minutes to hours) and not likely to cause injury or death from reduced growth, or physiological stress. This expectation is based on the general avoidance behaviors of salmon and the requirement to suspend construction when turbidity exceeds Regional Board standards. However, some juveniles that are exposed to turbidity plumes may be injured or killed by predatory fish that take advantage of disrupted normal behavior. Once fish migrate past the turbid water, normal feeding and migration behaviors are expected to resume.

The duration of turbidity plumes resulting from in-water construction related impacts of the barriers is expected to last 2 weeks. This corresponds to 50 percent of the month of April. Based on the salvage data gathered for the CVP/SWP, roughly 2.8 percent of the annual winter-run Chinook salmon salvage occurs during April. Prior to April, approximately 97 percent of the annual winter-run Chinook salmon salvage has occurred at the SWP and CVP diversions. Therefore, NMFS anticipates that no more than 1.5 percent of the annual winter-run Chinook salmon present in the South Delta are likely to be exposed to turbidity plumes originating from the construction of the temporary barriers. This is likely to be an overestimate since not all winter-run smolts in the South Delta will encounter the barriers in close enough proximity to be subjected to the turbidity plume.

According to the CVP/SWP salvage data, Central Valley spring-run Chinook salmon smolts primarily enter the South Delta in April. Nearly 68 percent of the annual salvage of spring-run sized Chinook salmon occurs during this month. Only 20 percent of the annual spring-run Chinook salmon salvage numbers occur prior to this time. Using the same rationale as was used for the winter-run sized Chinook salmon smolts, NMFS estimates that roughly 34 percent of the annual South Delta spring-run sized Chinook salmon salvage numbers will be present in the

South Delta during the period when turbidity plumes are likely and thus have the potential to encounter turbidity plumes from the TBP.

The CVP/SWP salvage records indicate that approximately 8 percent of the annual Central Valley steelhead DPS salvage occurs in April. NMFS predicts that half of these fish (4 percent) will have the potential to be exposed to the turbidity plumes originating with the installations of the barriers. However, NMFS also realizes that a much greater proportion of San Joaquin River basin steelhead will be exposed to the turbidity plumes than those originating from the Sacramento River basin due to their closer proximity to the action area and routes of migration through the South Delta. Estimates vary, but approximately 50 percent of the water flows in the mainstem San Joaquin River above the Head of Old River are diverted into the Old River channel under normal conditions. If emigrating steelhead smolts are moving past the HOR during construction, archival data from numerous studies, including the VAMP studies, indicates that approximately half of them should follow the flow split and move down the Old River channel. These fish would then have to pass at least 2 barriers to exit the South Delta; the HOR barrier and one of the three agricultural barriers depending on their route selection.

2. Hydrodynamics of Barrier Operations

a. *Farfield Effects*

The installation of the four temporary barriers within the channels of the South Delta creates far-reaching effects in the circulation of water through these channels. The primary effect of the HOR barrier is to reduce or eliminate the flow of water from the San Joaquin River into the channel of Old River at the head of the river. This forces the river flow to continue downstream towards the Port of Stockton. During the typical operational period of the spring HOR barrier, flows are elevated in the mainstem San Joaquin River due to additional reservoir releases conducted as part of the VAMP experiment. The additional flows, which originate in the three main tributaries to the San Joaquin River, the Stanislaus River, the Tuolumne River, and the Merced River, are designed to encourage outmigration of fall-run Chinook salmon smolts from the basin and enhance their survival downstream to the Delta. State and Federal fisheries biologist studying salmon survival through the Delta also believe that these measures enhance the survival of threatened Central Valley steelhead smolts emigrating from the San Joaquin River basin at the same time. Concurrent with the VAMP experiment reservoir releases, export pumping at the CVP and SWP facilities is reduced, thus theoretically reducing entrainment of fish towards the pumps and allowing a greater proportion to successfully transit the Delta and enter the estuary.

Although the HOR barrier was originally designed to block all of the flow into Old River, the permeability of the HOR barrier has been modified over the years. Due to complaints of lowered surface water elevations in the South Delta by the SDWA, up to 6 culverts have been installed in the HOR barrier since 2000 (2 culverts from 1997 to 2000). These culverts permit a fraction of the San Joaquin River water to pass through the barrier and alleviate water elevation problems in the South Delta during the operational periods of the HOR barrier in spring and fall. The operation of these culverts has increased the potential for a fraction of the outmigrating fish (both fall-run Chinook salmon and Central Valley steelhead) to be entrained into the culverts and passed into Old River below the barrier during spring operations. Work by the USFWS and CDFG has estimated that this entrainment is approximately 0.5 to 1.5 percent of the fish passing by the barrier based on the recovery of marked fish released upstream of the barrier's location.

This data was collected as part of the VAMP experiments during the period from 2000 to 2006 (San Joaquin River Group Authority 2001, 2002, 2003, 2004, 2005, 2006, 2007; DWR 2002, 2003, 2005, 2006a, 2006b). These data also indicated that there are distinct differences between nighttime and daytime entrainment rates, and less so with the status of the tides. The highest entrainment rates occur during the night as compared to the day. Flood tides following the low tide appear to have a greater entrainment rate than ebb tides following the high tide, but this relationship is weaker than the nighttime/daytime effect.

The installation of the barriers also creates alterations in the water circulation in the South Delta. The barriers create a delay in the tidal signal between the channels upstream of the barriers and the downstream sections of the channels below the barriers. The barriers also create differences in water elevations between the upstream segments above the barriers and those segments below the barriers. In addition to the increases in water elevations, alterations in the net flows and their direction within the channels of the South Delta occur with the installation of the temporary barriers. DWR has modeled these flows using its Delta Simulation Model (DSM2-Hydro). In general, the average net flows in the South Delta channels are reduced or reversed when the barriers are in place. Prior to barrier installation, net flows in Old River and Grantline/Fabian and Bell Canal are downstream and directly influenced by flows entering the Old River channel from the mainstem San Joaquin River at HOR as well as pumping rates at the CVP and SWP facilities. Flows in MR are harder to predict. When flows in the mainstem San Joaquin River at Vernalis are high, then flows entering the South Delta channels are higher and Middle River tends to have a net positive flow downstream along its entire length. Conversely, when San Joaquin River flows are low, then the net flow in lower MR tends to be negative and the flows entering from Old River near Undine Road are "balanced" by this inflow of water from downstream. Once the ORT, MR and HOR barriers are installed ("normal" VAMP barrier conditions), the net flows above the ORT and MR barriers generally become negative and flow proceeds in an upstream direction. Flows in GLC remain positive and net flows proceed in a downstream direction towards the CVP and SWP water intakes. Once the HOR barrier is removed at the end of the VAMP experiment (or sometimes later), net positive flows resume in the upper portion of Old River and flow enters both the lower Old River channel and Middle River channel below their split. Flows from upstream may become "balanced" by net negative flows originating from downstream creating areas of null flows in the interior sections of the channels. This condition is more pronounced as the demand for irrigation water increases within the interior of the South Delta and inflow from the San Joaquin River is low (*i.e.*, flows below approximately 2,000 cfs). The flow patterns in the interior of the South Delta under these parameters creates a "hydraulic trap" for particles (or fish) moving with the river's flow. These alterations in the flow patterns in the south Delta reduce the ability of emigrating salmonids, particularly the Central Valley steelhead from the San Joaquin River basin, to successfully travel through the region towards the western edge of the Delta. These changes will create a confusing flow signal for any emigrating fish within the affected areas, diminishing the fish's ability to find a clear route towards the ocean. Increases in travel time through the south Delta channels are expected to expose fish to higher levels of predation, raise the risk of entrainment into any one of the thousands of small agricultural water diversions found in the area, and prolong the time that fish are exposed to reaches with degraded water quality.

During the period when the barriers are installed in the South Delta, the hydrodynamics of the Delta interior to the north are also affected. Under the influence of pumping at the CVP and SWP, water is drawn southwards from the lower San Joaquin River near McDonald, Mandeville and Medford Islands down the channels of Old River, MR, Columbia Cut, and Turner Cut. This creates net negative flows in these channels and water moves upstream towards the CVP and

SWP diversion points in the South Delta. Any fish that was successful in staying in the main channel of the San Joaquin River past the HOR still has the possibility of being drawn back into the South Delta through these aforementioned waterways under the influence of the pumping actions of the CVP and SWP (Vogel 2004). For fish that are drawn into these channels, the risk of predation, entrainment by agricultural diversions, and exposure to degraded water quality increases. These factors are expected to reduce their chances of survival.

The barriers also impact water quality parameters, although to varying degrees. Based on the data provided by the annual reports submitted by DWR (2001 through 2005), specific conductance is generally higher upstream of the barriers than below. Typically, Old River has the highest specific conductance while Middle River has the lowest. In 2005, this relationship did not hold, as flows from the San Joaquin River were much higher than in previous years, and the South Delta channels were all well flushed throughout the summer period. Dissolved oxygen and water temperature also appear to show a strong correlation with season as represented by ambient air temperature. As ambient air temperature increases, water temperature also increases, while DO levels decline. Barrier effects may contribute to the creation of DO sags around the barriers (ORT and GLC) and within the interior sections of the South Delta channels due to flow conditions (null zones), input of irrigation return water, input of waste waters from sanitation plants, nutrient loading, and excessive primary productivity depleting nighttime DO levels through respiration. These decreases in ambient water quality parameters would have negative impacts on the survival of any salmonid found in the affected waterways. Lower DO levels would lessen the swimming ability of migrating smolts and thus reduce the likelihood of successfully escaping predators better suited to low DO environmental conditions. Similarly, any green sturgeon that was caught in the interior of the south Delta during the installation of the barriers has the potential to be exposed to this lowered water quality until they found their way out of the south Delta or the barriers are removed in the fall.

b. *Nearfield Effects*

The three agricultural barriers will function as open channel weirs within the waterways of the South Delta. The fourth barrier, the HOR barrier, functions as semi-permeable dam with operable culverts to allow controlled flows of water to pass through the structure. In general, water will flow over the crest of the three agricultural barriers and create a turbulent flow field downstream of the barriers. The characteristics of the flow field, however, will not remain static as water elevation and flow direction will change with the tidal cycle. Flow will typically be bi-directional, and water elevation will have both an ascending limb and descending limb, based on the point of the tidal cycle in which the observations are made.

The following is a generalization of the complex hydraulic environment created by the agricultural barriers within the channels of the South Delta. Concepts are based on information provided in the introductory reference text for open channel hydraulics by Chanson (2004). On an incoming tide, the water elevation downstream of the structures will be below the elevation of the weir crest (*e.g.*, +1 foot mean sea level [msl]) and hence the upstream water surface elevation. The incoming tide will encounter the rock barrier and water surface levels will increase in elevation on the downstream side of the barrier. At the point of contact with the barrier, net water velocity will diminish to zero, since upstream flow is negated by the barrier. Flow from upstream of the barrier will continue to flow over the weir, creating a "riffle" over the downstream slope of the rock barrier before dissipating its energy in the "plunge pool" below the rock barrier. Depending on the differential in head between the upstream and downstream sides of the rock barrier, a significant hydraulic jump can be formed when energy in the faster velocity flow coming over the weir is dissipated by the downstream water mass in the plunge pool. It is expected that a complex circulation pattern will be set up by the formation of the hydraulic jump at the interface of the downstream water body and the flow of higher velocity water coming over the weir crest (and through the submerged culverts when they are tied open). The tongue of water flowing over the weir (the weirs are less than the width of their respective channels) will create counter circulating flow cells below the water surface and to either side of the main flow line. NMFS expects these circulation patterns to concentrate fish, such as listed salmonids, immediately downstream of the barrier structures. In addition to the downstream conditions described, flow over the top of the weir is likely to create a hydraulic "cushion" on the upstream side of the rock barriers below the elevation of the weir crest. NMFS expects that these areas of reduced velocity will also serve to concentrate fish prior to their passage over the top of the weir. In addition, these areas of reduced flow velocities serve as ambush points for predatory fish to prey on the concentrated schools of smaller fish in front of the barrier. These hydraulic conditions are expected to have adverse effects upon listed salmonids traveling through the reaches occupied by the agricultural barriers.

In addition to flow over the top of the barrier's weir, additional flow from upstream can pass downstream through the submerged culverts during the early portion of the barrier's installation season. During this early stage of the barrier season, the agricultural barriers have their culverts tied open to allow tidal flow to pass through them and the HOR barrier has its slide gates raised to allow the San Joaquin River flow to pass through the culvert into the Old River channel. Normally, the tidal flap gates would close and prevent the ebb tide from flowing through the culverts in the downstream direction. As the tide reaches full flood and its elevation matches the water level upstream of the barriers, water is expected to move upstream through both the submerged culverts, and across the top of weir. In order for water movement to pass upstream through the 48-inch diameter culverts, the elevation head has to be higher on the downstream side than the upstream side of the barrier. This only occurs when the downstream surface elevations are above the height of the weir crest and the surface elevations upstream of the barriers. NMFS expects that fish below the weir will move with the upstream flow, passing through both the culverts and across the top of the barrier's weir with the incoming tide. Similar to the circulation conditions already described for water flowing downstream over the weir crests, NMFS expects water flowing upstream over the weirs during the flood stage of the tide to exhibit turbulent characteristics. Fish passing through this turbulent tongue of water will experience disorientation and become more susceptible to predation.

In summary, NMFS anticipates that the installation of the barriers will create hydraulic conditions that will impede free passage of fish through the channels of the South Delta. Water flow through the channels will be redirected, and the residency time of fish passing through the channels of the South Delta will be increased due to the changes in flow patterns. Furthermore, after passing through the San Joaquin River reach adjacent to the Port of Stockton and lower Roberts Island, a proportion of the fish that remained in the mainstem of the San Joaquin River will subsequently be entrained into the channels leading southwards under the influence of the CVP/SWP water diversion pumps, thus negating the benefits of the HOR barrier. In addition, the barriers will create nearfield hydraulic conditions that will subject migrating fish to increased turbulence and disorientation than is normal for an unobstructed channel. The barriers will also create obstructions that will concentrate fish into confined areas of the channel prior to passing through the reach with the barrier structure. These effects will increase their risk of predation by larger fish such as striped bass and largemouth bass. Predation effects will be discussed in the next section.

3. Predation Risks Associated with the Barriers

Predatory fish are known to congregate below manmade barriers in rivers to feed on prey species passing through the barrier system. Studies of striped bass predation exist for several different salmonid populations. Blackwell and Juanes (1998) documented increased predation on juvenile Atlantic salmon smolts (*Salmo salar*) by striped bass (*Morone saxatilis*) passing over Essex Dam (a low head dam) on the Merrimack River in Massachusetts. Examinations of stomach contents from the striped bass captured below the dam indicated a high rate of predation on Atlantic salmon smolts during their downstream emigration to the Atlantic Ocean. Salmon smolts accounted for nearly 49 percent of the recovered prey species from striped bass that had stomachs containing prey, and composed nearly 80 percent of the total mass of prey remains recovered from those fish. The average size of the ingested smolts was approximately 150 mm and ranged from about 90 mm to 190 mm. Striped bass that had consumed smolts ranged in size from 38 to 69 cm in length. A similar level of predation by striped bass on fall-run Chinook salmon was observed by Merz (no date) on the Mokelumne River below the Woodbridge Irrigation Dam. In this study striped bass were caught by electrofishing and angling and their stomach contents examined. A high concentration of striped bass were found immediately below the dam during the spring outmigration of fall-run Chinook salmon, and Merz estimated that approximately 11 to 28 percent of the fall-run Chinook salmon smolts passing the dam were consumed by the striped bass congregating below the structure. This value rose to almost 50 percent when unidentified, but suspected Chinook salmon smolt remains were included in the analysis. In Coos Bay, Oregon, the decline of fall-run Chinook salmon coincided with large increases in the local striped bass populations and reductions in salmon spawning habitat. Subsequent reductions in the striped bass populations and improvements in the salmon spawning habitats coincided with a salmon population recovery (Johnson *et al.* 1992). Therefore, the presence of striped bass, in combination with the physical structures of the four barriers, is expected to increase the predation rate of salmonid smolts in the South Delta system during their outmigration.

Delta sport fisherman routinely target large striped bass in the eastern Delta's lower Mokelumne River system when steelhead smolt releases are being made by the Mokelumne River Fish Hatchery. Fishermen typically are most successful when using artificial lures that resemble rainbow trout. Walters *et al.* (1997) confirmed that striped bass in the Colorado River below Hoover Dam were a factor in the poor return of small stocked rainbow trout in creel surveys. Fish less than 250 mm were found to be susceptible to striped bass predation in the Hoover Dam tailwaters. This is an equivalent size to the Central Valley steelhead smolts entering the Delta waterways from upstream tributaries. Consequently, striped bass are expected to contribute significantly to the predation of steelhead smolts migrating through the South Delta action area.

In both 2006 and 2007, Chinook salmon smolts were tagged with acoustical transmitters as part of the VAMP experiments on the San Joaquin River (San Joaquin River Group Authority 2006, 2007). In 2006, acoustic-tagged salmon smolts were released at Mossdale and Dos Reis in the lower San Joaquin River near HOR under high flow conditions (no HOR barrier). Five acoustic receivers were placed at different locations in the South Delta to monitor for fish passage (Old River below the HOR barrier, Brandt Bridge over the lower San Joaquin River near the City of Lathrop, Turner Cut, Middle River near Bacon Island, and the San Joaquin River near Mandeville Island). The first release of 32 fish at Mossdale indicated that 25 fish (78 percent) went down the Old River channel. This was higher than expected based on the flow split (53 percent of flow went down Old River). Three of these 25 fish were detected later at Middle River near Bacon Island, but not at any of the receivers located farther downstream. Likewise, five of the 32 fish released were detected at the Brandt Bridge receiver location downstream of Mossdale, but not at the Turner Cut or San Joaquin River at Mandeville Island receivers. Two of the tagged fish released at Mossdale were never detected at the first two downstream monitoring stations and assumed to have been lost to predation within close proximity of the release point. The second release date split fish into a 35 fish group released at Mossdale and a 33 fish group at Dos Reis. The second Mossdale release indicated that only 40 percent of the released fish went down Old River when the flow split was 51 percent. Of these two groups, assumed predation ranged from 29 percent (Mossdale) to 58 percent (Dos Reis) within the river reaches to the first detectors (Old River at Head and Brandt Bridge). High levels of predation were observed just downstream of HOR where a deep scour hole occurs at a bend in the river. Actively feeding striped bass were observed, and 5 stationary tags were detected within the hole, assumed to have been defecated from predatory fish. An additional 8 tags were detected downstream of the river split adjacent to structures in the river (irrigation pump houses).

The 2006 data indicate that predation is a major factor in the loss of salmon smolts in the system. This general finding is supported by the 2007 data in which nearly 1,000 acoustically tagged fish were released. In 2007, the HOR barrier was installed, unlike 2006 when high flows prevented its installation. Fish were released from Durham Ferry (the normal upstream release point for VAMP studies), Mossdale, Dos Reis, Stockton, and below the HOR barrier on Old River. The number of detections declined significantly the farther the receivers were positioned downstream from the release points. A very high concentration of mortalities occurred adjacent to the Highway 4 Bridge over the San Joaquin River near Stockton. The cause of this high incidence of mortality appears to be related to water quality rather than predation, and is being investigated further. However, the declines in the number of detections at other receiver points indicate that attrition in the number of fish moving downstream is significant. Of those fish released below the HOR barrier on Old River, approximately 75 percent made it to the vicinity of the CVP and SWP intakes after the first release date. Only about 40 percent reached this point after the second release date. In the second series of releases, it appears that predatory fish keyed in on the tagged smolts as they moved through the South Delta channels below the HOR barrier. This may be correlated with a "learned response" by predators associating with the barriers and taking advantage of the hydraulics created by the barriers following the first release. NMFS staff (J. Stuart) has observed striped bass pushing schools of threadfin shad up against the barriers during the VAMP period prior to creating a "feeding frenzy" on the corralled fish. There also appears to be an elevated level of attrition between Durham Ferry and Mossdale (30 to 40 percent). Based on previous studies, NMFS assumes that predation accounts for most of these losses.

When the HOR barrier is not installed, approximately half of the outmigrating steelhead smolts from the San Joaquin River basin are expected to follow the river's flow split into the channels of the South Delta as previously mentioned. This event typically occurs when flows are too high to safely install the barrier (flows > 5,000 cfs). These high flows will help to move fish through the South Delta quickly and it is believed that predation risks will be reduced due to the shorter residence time in the South Delta, although these hypotheses have not been statistically proven. Steelhead smolts are expected to benefit under these conditions, as are other listed fish species. A unique situation will occur in 2008 with the implementation of a court order that prevents installation of the HOR barrier to protect delta smelt in the lower reaches of the Middle and Old Rivers. Although the HOR barrier will not be installed even though the ambient flows would allow it, the three agricultural barriers are planned to be installed to benefit agricultural diverters in the South Delta. Under this arrangement, steelhead smolts from the San Joaquin River basin will be able to enter the South Delta and be subjected to the full effects of the three agricultural barriers. NMFS anticipates that survival will be low under these conditions and will negatively affect the Central Valley steelhead population in the San Joaquin Basin. Reduced survival of emigrating smolts through the South Delta will diminish the proportion of fish reaching the ocean and will be carried forward to reduce adult escapement numbers several years into the future. Reduced numbers of returning adults will reduce the viability of the San Joaquin River basin's steelhead population by reducing the potential number of progeny produced in the natal streams in subsequent years.

4. Effects of Proposed NPB on Listed Anadromous Fish Species

Pile Driving Effects. The installation and removal of four 12- to 16-inch diameter steel piles and the bubble curtain structure at the head of Old River has the potential to harass and displace fish present in the general area of the construction activity. NMFS has established interim criteria for evaluating underwater noise impacts from pile driving on fish. These criteria are defined in the document entitled "Agreement in Principal for Interim Criteria for Injury to Fish from Pile Driving Activities" dated June 12, 2008 (NMFS 2008). This agreement identifies a peak sound pressure level of 206 decibels (dB) and an accumulated sound exposure level (SEL)[1] of 187 dB: re 1μpascal as thresholds for injury to fish. For fish less than 2 g, the accumulated SEL threshold is reduced to 183 dB. Although there has been no formal agreement on a "behavioral" threshold, NMFS uses 150 dB-root mean square (RMS) as the threshold for creating adverse behavioral effects in exposed fish (NMFS 2009).

Pile driving noise modeling, using NMFS' Underwater Noise Calculation Spreadsheet model (NMFS 2009), indicates that the installation of the piles would not result in peak sounds greater than 171 dB. The Compendium of Pile Driving Sound Data (California Department of Transportation 2007) provides sound level data on a variety of pile sizes and driver types. Data on vibratory driving of 12-inch diameter steel piles are available but none is available for 16-inch diameter steel piles. NMFS considers the data for 12-inch diameter steel piles to be representative of the types of piles to be used and indicates the following exposure levels as measured at a distance of 10 m from the source pile:

- Peak[2] = 171 dB
- RMS = 155 dB
- Sound exposure level (SEL [for 1 second of vibratory driving]) = 155 dB.

In the absence of site-specific data, NMFS recommends using an underwater attenuation rate of 4.5 dB per doubling of distance (NMFS 2009). It also supports the notion that sound levels of less than 150 dB do not contribute the accumulated SEL for the purposes of assessing injury (NMFS 2009). Using this assumption and attenuation rate the calculated distance to each of the applicable thresholds is as follows:

- Distance to 206 dB_{peak} = less than 1 meter
- Distance to 150 dB_{RMS} = 22 meters
- Distance to 187 dB-$SEL_{accumulated}$ = 22 meters (for fish > 2 g)

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[1] Accumulated SEL ($SEL_{accumulated}$) is the cumulative SEL resulting from successive pile strikes. $SEL_{accumulated}$ is based on the number of pile strikes and the SEL per strike; the assumption is made that all pile strikes are of the same SEL.

[2] Peak sound pressure refers to the highest absolute value of a measured waveform (i.e., sound pressure pulse as a function of time). Sound exposure level (SEL) is defined as the constant sound level acting for one second, which has the same amount of acoustic energy as the original sound. Expressed another way, the sound exposure level is a measure of the sound energy in a single pile driver strike.

- Distance to 183 dB-$SEL_{accumulated}$ = 22 meters (for fish < 2 g)

Additionally, the increased turbidity levels associated with construction may negatively impact individual fish temporarily through reduced availability of food, reduced feeding efficiency, and exposure to toxic sediments released into the water column. These potential effects would be minimal because:

- The effects would be temporary (4 days for installation and 5 days for removal) and would only occur in 2009;

- A vibratory method of pile installation will be used which minimizes disturbances to fish over other impact-type pile driving methods;

- For most activities, the effects of pile driving noise on fish would be likely be limited to avoidance behavior in response to movements, noises, and shadows caused by construction personnel and equipment operating in or adjacent to the water body. Additionally, the duration of pile driving is minimal and would be limited to 2 hours;

- Only a very small channel area would be disturbed or affected by construction; and

- Most fish are expected to move away from the area of disturbance.

a. Hydrodynamic Impacts on Listed Anadromous Fish Species

The NPB is intended to avoid any hydrodynamic changes in South Delta channels by allowing the natural flow split at the head of Old River from San Joaquin River to occur. This would minimize the amount of water pulled from Columbia and Turner Cuts export operations, thus limiting the reverse flows in South Delta channels and their associated negative effects on migrating fish. This latter condition is typically observed when the temporary rock barrier is installed at the Head of Old River as previously described. The experimental NPB is intended to reduce the vulnerability of emigrating salmonids, including both fall-run Chinook salmon (primary target species) and Central Valley steelhead (secondary target species) to the stressors associated with the channels of the South Delta. The barrier is intended to separate the emigrating fish from the water that would normally flow down the Old River channel. Since there would be no changes in hydrodynamics, there would be no impacts on fish related to water quality, exposure to agricultural diversions, food availability, and distribution of listed species that are not currently part of the baseline condition (*i.e.*, the winter no barriers installed period).

b. Passage Impacts On Listed Anadromous Fish Species

(1) Spring- and winter-run Chinook salmon. Adult spring- and winter-run Chinook salmon are unlikely to experience an impact to migration. These salmon races spawn only in the Sacramento River basin and therefore are unlikely to use the south Delta as a migration corridor. Additionally, it appears that even San Joaquin River basin fall-run Chinook salmon migrate upstream mainly through the mainstem of the San Joaquin River rather than through Delta sloughs. Hallock *et al.* (1970) found that the majority of San Joaquin River basin Chinook salmon migrated through the mainstem river and not through the Delta. Additionally, CDFG Fish Monitoring data suggests that adult salmon are rare in the south

Delta. Large mesh drift nets were used to monitor the presence of fall- and late fall–run adult Chinook salmon during September 1997 and 1998 at Grant Line Canal, Middle River, and Old River at Tracy. In over 74 hours of sampling, only a single adult Chinook salmon was captured.

Juvenile spring- and winter-run Chinook salmon are also unlikely to experience a migration impact caused by the NPB. Because these races of salmon originate in the Sacramento River basin, they are unlikely to travel through the San Joaquin River and the south Delta during their downstream migration. In order for the NPB to pose a downstream migration barrier, these fish would have to migrate downstream in the Sacramento River, then proceed upstream in the San Joaquin River for several miles, and then back downstream through Old River. The Delta Cross Channel Gates are currently operated in a manner to greatly minimize the potential for spring- and winter-run Chinook salmon smolts to enter the central Delta during the time that the NPB is operated. Thus, direct passage impacts are highly unlikely for juvenile spring- or winter-run Chinook salmon.

*(2) **Central Valley steelhead**.* The NPB has the potential to beneficially alter passage and migration for Central Valley steelhead originating in the San Joaquin River basin. Several monitoring programs, including salvage operations at the SWP and CVP facilities, and incidental catches in salmon monitoring programs (Mossdale trawl, and the RSTs at Caswell Park and Oakdale on the Stanislaus River), indicate that juveniles (and potentially run-back adults – "kelts") may be present in the south Delta during the period that the NPB is operational (DWR 2000). If steelhead encounter the NPB and are deterred by it, remaining within the main channel of the San Joaquin River and moving downstream towards Stockton, then a beneficial change in steelhead migration has occurred. If emigrating steelhead (smolts and adults) are not deterred by the NPB and pass through the barrier, then there would be no change in steelhead migration behavior from the current baseline conditions. Fish would choose one of the pathways to follow and proceed downstream on their chosen route. NMFS does not anticipate that an encounter with the air bubble curtain and its associated lights and sound would have any adverse effects on steelhead. However, steelhead choosing the Old River migratory route are expected to have a higher loss rate than fish remaining in the main channel of the San Joaquin River. The extent of the benefit cannot be determined because the response of steelhead to the NPB has not been tested, and therefore the proportion of fish deterred by the NPB is unknown. It is unlikely that emigrating steelhead smolts from the Sacramento River basin would be found in the vicinity of the NPB site on the San Joaquin River.

*(3) **Southern DPS of green sturgeon**.* NMFS anticipates that few if any adult green sturgeon would be found in the vicinity of the NPB. Historical and recent monitoring efforts have recorded only adult white sturgeon presence in the area adjacent to the NPB location at the Head of Old River. NMFS anticipates that juvenile and sub-adult green sturgeon may be present in the general area of the NPB due to their presence in the south Delta at the fish collection facilities of the CVP and SWP. During the winter open channel configuration in the south Delta, fish would have free passage to move into the area from the channels of the south Delta, or alternatively could move upstream into the San Joaquin River from the Deep Water Ship Channel and, thus, could be present at the location of the NPB during its period of operation. The barrier is designed to have a 1- to 2-foot clearance below the support beams to allow demersal fish to pass under it. However, green sturgeon response to the NPB is unknown, and fish may be deterred from passing underneath the barrier even though clearance has been provided. In such a case, the green sturgeon would be free to fall back downstream and retrace the rout it took to reach the NPB site through the Delta.

5. Summary of Project Effects on Listed Anadromous Fish Species

a. Central Valley Spring-Run Chinook Salmon

The spring installation for the temporary barriers coincides with the peak of Central Valley spring-run Chinook salmon smolt outmigration in the Delta as measured by the salvage records from the CVP and SWP (see Appendix A: Table 11). As described previously in *Section V.B.(1)*, a small proportion of the spring-run Chinook salmon are expected to be present in the action area during the actual construction phase of the barriers. The construction phase of the TBP is expected to result primarily in conditions that harass exposed fish through elevated sounds and turbidity, but not result in conditions that would cause imminent mortality directly related to the construction activity.

Approximately two thirds (67 percent) of the annual spring-run Chinook salmon salvage occurs in the month of April as indicated by the salvage records from 1999 through 2007. By May, the proportion of spring-run Chinook salmon outmigrants has declined markedly, falling to approximately 11.5 percent of the annual total salvage numbers. Outmigration of spring-run Chinook salmon smolts has essentially ended by the end of June (1.3 percent of annual total salvage). NMFS believes that juveniles of the spring-run Chinook salmon population that have been drawn into the South Delta by the actions of the CVP and SWP pumps during this time period become susceptible to the effects of the barriers. In particular those fish that move with the tidal circulation patterns in the western channels of the South Delta (Middle River near Union Point, Old River near the CVP facilities, and the Grant Line Canal system near the SWP Clifton Court radial gates) have a high probability of encountering adverse predator conditions surrounding the ORT, MR, and GLC barriers. As explained in the previous sections, flow patterns in the interior of the South Delta are altered due to the installation of the barriers, and unique nearfield flow conditions are created at the barriers themselves. This environment enhances the potential risk of mortality for Chinook salmon smolts in the South Delta. The creation of barriers to free movements of fish in the main channels, the concentration of predators at key "choke points" in those channels (*i.e.*, at the barrier locations), and the creation of a "recirculating" flow pattern elevate the risk of mortality for those Chinook salmon smolts entering the action area.

The experimental NPB is not anticipated to have any discernable effects upon Central Valley spring-run Chinook salmon due to its location at the Head of Old River and its distance from the CVP and SWP export facilities. Spring-run Chinook salmon are not anticipated to be present in any significant numbers at the Head of Old River as they would have to swim through miles of South Delta channels to reach the NPB location, while swimming against a net flow from the upper San Joaquin River leading towards the facilities from the open Head of Old River channel. NMFS considers this occurrence to be unlikely. Any fish that were to encounter the NPB from the downstream side would probably be deterred from swimming through the air bubble curtain and return downstream.

b. Sacramento River Winter-Run Chinook Salmon

Slightly less than 3 percent of the average annual winter-run Chinook salmon salvage occurs in the month of April, according to data from the CVP and SWP salvage records (1999-2007). For the months of May and June, the number of winter-run Chinook salmon smolts collected at the

CVP and SWP facilities falls to approximately 0.5 percent of the annual salvage numbers. This indicates that few winter-run Chinook salmon smolts would be exposed to the construction actions of the TBP [see *Section V.B.(1)*] and of those that were exposed to the construction activities, most would experience adverse conditions on the level of harassment rather than levels resulting in injury or mortality. In contrast, those winter-run Chinook salmon smolts present in the action area following completion of the barriers would be more vulnerable to predation due to the higher concentration of predators in the area and the alteration in flow patterns created by the barriers that would enhance predator success. The experimental NPB will be operated during a period of time when the probability of winter-run Chinook salmon smolts being present in the South Delta is low, as indicated by the salvage data. The risk to winter-run Chinook salmon smolts is further reduced by the NPB's distance from the export facilities and the net direction of flow moving through the channels of the South Delta during the proposed operational period. As previously described for the spring-run Chinook salmon, winter-run Chinook salmon smolts would have to swim through miles of South Delta channels against the ambient river flow to reach the location of the NPB at the Head of Old River. NMFS considers this to be an unlikely occurrence. Any fish that were to encounter the NPB from the downstream side would probably be deterred from swimming through the air bubble curtain and return downstream.

c. Central Valley Steelhead

The data from the CVP and SWP salvage records indicate that approximately 9 percent of the annual steelhead salvage occurs between April and the end of June (April – 7 percent, May – 1.2 percent, June – 1 percent). Unlike the winter-run and spring-run Chinook salmon, Central Valley steelhead occur in both the Sacramento and San Joaquin River basins. Therefore, this species can enter the South Delta action area from both Head of Old River on the eastern side of the South Delta and also from the western side of the South Delta due to the influence of the state and Federal pumps pulling water and fish southwards through the Delta from both the Sacramento River basin and the San Joaquin River mainstem. Due to the geographic location of the barriers in the South Delta, the populations of steelhead originating in the San Joaquin River basin are at a higher risk of being affected by the construction and operation of the TBP due to their proximity and the emigration routes they must follow to access the ocean. Even when the HOR barrier is installed, steelhead that pass down the mainstem of the San Joaquin River towards Stockton must also face the concentrations of predators that inhabit this stretch of river, as described in the accounts for the acoustic tagging studies done in the VAMP experiments. Survival appears to be enhanced for Chinook salmon smolts following this route, as compared to those that take a path through the South Delta. However, overall survival is still quite low for either path taken based on the survival estimates generated from fish recoveries. NMFS expects that steelhead smolts, although larger than fall-run Chinook salmon smolts, would also face high levels of predation, particularly from striped bass, while emigrating down the mainstem of the San Joaquin River. Recent studies by DWR in Clifton Court Forebay (DWR 2008) examining the rate of loss of acoustically tagged steelhead smolts within the forebay (assumed to be primarily the result of predation) indicate that steelhead smolts and Chinook salmon smolts have similar levels of loss, even though the steelhead are considerably larger fish. Following the removal of the HOR barrier, steelhead smolts may enter the channels of the South Delta as early as mid-May, where they would encounter the effects of the agricultural barriers, including reversed flows, turbulent water flows over the barriers, and elevated concentrations of predators associated with the barriers.

The experimental NPB will be operated during a period of time when the probability of Central Valley steelhead from the San Joaquin River Basin being present in the South Delta is high based on historical monitoring of the rotary screw traps on the Stanislaus River and the recovery of steelhead smolts in the Kodiak trawls conducted at Mossdale by CDFG and USFWS during the spring. The NPB is hypothesized to deter steelhead smolts, just as it has been shown to deter Chinook salmon smolts in laboratory testing. If the bubble curtain performs as expected, steelhead smolts will be deterred from entering the Old River channel from the main channel of the San Joaquin River, and thus continue downstream in the San Joaquin River towards the Port of Stockton. Fish will not move into Old River and, therefore, will not encounter the entrainment and predation risks associated with the channels of the South Delta. Conversely, any fish that passes through the bubble curtain into Old River will encounter a higher risk of entrainment and predation while transiting these pathways. However, this fate is the same as in the "no barrier" condition that exists in the baseline condition.

d. Southern DPS of North American Green Sturgeon

NMFS anticipates that green sturgeon will be present in the South Delta during the spring installation of the temporary barriers. Based on the salvage recoveries of green sturgeon at the CVP and SWP, they are most likely to be in the western channels of the South Delta, but their presence in the mainstem of the San Joaquin River cannot be completely ruled out. Green sturgeon have the potential to become trapped behind the barriers following their construction. Based on the observed behavior of green sturgeon, they are unlikely to swim over the crest of the weir to escape confinement upstream of the barriers. However, prior to the full operation of the barriers, movement upstream and downstream might be possible through the culverts. Following full barrier operations, this becomes impossible due to the tidal flaps closing on the outgoing tide, thus blocking passage downstream through the culverts. The only avenue of escape from the South Delta channels would be to swim upriver to the confluence of the Old River channel with the San Joaquin River and then swim downstream within the San Joaquin River mainstem to the DWSC. Should green sturgeon become entrapped upstream of the barriers, they would be unable to escape the increasing warming of the water in the South Delta channels as summertime air temperatures increased in the region. Summer water temperatures can exceed 80° F in the South Delta. As water temperatures increase, DO also declines creating zones of hypoxia which may further block movements in the South Delta. Summertime water quality also decreases in the South Delta channels due to increasing agricultural discharges and stagnation of flushing flows. NMFS does not anticipate that the juvenile sturgeon present in the South Delta action area will be subject to predation by striped bass or other piscivores due to their large size and protective scutes.

The NPB will be operated during a period when juvenile, adult, and subadult green sturgeon may be present in the South Delta. As described previously, the probability of green sturgeon presence is higher in the South Delta channels nearer to the export facilities, rather than nearer to the Head of Old River location of the bubble curtain device. The NPB device will be positioned 0.3m to 0.6m above the channel bottom, providing sufficient clearance to allow passage of benthic fish species beneath it, including green sturgeon. However, the behavioral response to passage by benthic-oriented fish is unknown at this time. The short duration of the NPB experiment will not create a permanent obstruction to passage, with the anticipated experiment lasting approximately 31 days. This would be the maximum period of delay in the movements of green sturgeon if they do not volitionally pass under the air bubble curtain during operations.

6. <u>Project Effects on Critical Habitat</u>

As described earlier, the installation of the four temporary barriers will only affect designated critical habitat for Central Valley steelhead. It will not affect designated critical habitat for Sacramento River winter-run or Central Valley spring-run Chinook salmon. The installation of the four temporary barriers will also affect the proposed critical habitat of the Southern DPS of green sturgeon occurring in the South Delta.

The installation of the four barriers directly impacts approximately 63,000 square feet of channel bottom (1.45 acres). The spring HOR barrier installation footprint has dimensions of approximately 250 feet by 85 feet (19,125 square feet), while the footprint of its fall installation is slightly smaller at 225 feet by 55 feet (12,375 square feet). The ORT barrier has a footprint of approximately 250 feet by 60 feet (15,000 square feet). The GLC barrier has a similar sized footprint of 300 feet by 50 feet (15,000 square feet). The MR barrier has the smallest agricultural barrier footprint of 270 feet by 50 feet (13,500 square feet). The annual duration of the physical "smothering" of the channel bottom by the barriers' rocky construction substrate lasts approximately eight months (April through November) for the three agricultural barriers. The springtime HOR barrier lasts approximately 45 to 60 days from the start of construction to the removal of the barrier in late May/early June. Likewise, the fall HOR barrier may remain in the channel for up to 60 days, depending on the management goals of the CDFG. NMFS expects that the regular disturbance of the channel substrate by the installation and removal of the barriers will prevent the establishment of a normal climax benthic community within the footprints of the four barriers. The high level of disturbance experienced within these areas would preferentially favor non-native species which could rapidly colonize the disturbed substrate.

The installation of the temporary barriers is anticipated to affect nearly 25 miles of South Delta waterways lying between the locations of the four barriers. NMFS expects that the hydrological impacts of the barriers will affect the natural communities within these channels, primarily due to changes in the length of inundation during each tidal cycle as reflected in the differences between the barrier installation season and the "natural" no-barrier condition in winter. In addition, hydrological changes will affect the ability of migrating salmonids to freely pass through the action area due to the flow impediments created by the barriers.

The installation of the NPB will temporarily impact approximately 2,200 square feet of channel bottom (370 feet long by 6 feet wide). The surface area affected by the actual piles driven into the channel bottom accounts for approximately 5.6 square feet of channel substrate. The remainder of the affected area is the general footprint of the air bubble curtain when it is in operation, *i.e.*, 370 feet long with a width of approximately 6 feet, depending on current. The barrier will only impact the channel habitat for a period of approximately 1 month, after which, it will be removed entirely from the channel, including the 4 piles.

The channels of the South Delta have been extensively modified by human activities. The channel edges have been heavily riprapped and the channels no longer have normal fluvial function. Channels cannot migrate within their natural floodplain, but rather are constricted to the region between the two leveed banks. Riparian growth has generally been limited to narrow bands along the base of the levee banks where siltation has allowed shallow berms of sediment to accumulate. Along these narrow bands, stands of tules and rushes have taken root and created pockets of emergent vegetation, which in turn have created small low-lying islands, particularly in Middle River and the central portion of Old River. Some of these islands have sufficient elevation to allow shrubs and trees to grow on them. In winter, when the temporary barriers are removed, the channels and their stands of emergent vegetation are exposed to the full tidal range of approximately 5 feet (-2 feet msl to +3 feet msl). When the temporary barriers are in place, the tidal range is muted, and the lower range of the tide is held artificially high (*i.e.*, +1 foot msl). The "intertidal" range is reduced and vegetation that would normally have been exposed at low tide is submerged during the periods when the barriers are in use by up to 3 feet of water. This inundation pattern is likely to change the profile of the emergent vegetation community.

Likewise, as explained previously, the barriers create impediments to free movement of fish within the channels of the South Delta affected by the placement of the barriers. They also create structure which attracts predatory fish and enhances their foraging success on juvenile salmonids passing through the reaches affected by the placement of the barriers.

VI. CUMULATIVE EFFECTS

For purposes of the ESA, cumulative effects are defined as the effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR §402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultations pursuant to section 7 of the ESA.

A. Agricultural Practices

Agricultural practices in the Delta may adversely affect riparian and wetland habitats through upland modifications of the watershed that lead to increased siltation or reductions in water flow in stream channels flowing into the Delta. Unscreened agricultural diversions throughout the Delta entrain fish including juvenile salmonids. Grazing activities from dairy and cattle operations can degrade or reduce suitable critical habitat for listed salmonids by increasing erosion and sedimentation as well as introducing nitrogen, ammonia, and other nutrients into the watershed, which then flow into the receiving waters of the Delta. Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may adversely affect salmonid reproductive success and survival rates (Dubrovsky *et al.* 1998, 2000; Daughton 2003).

B. Increased Urbanization

The Delta, East Bay, and Sacramento regions, which include portions of Contra Costa, Alameda, Sacramento, San Joaquin, Solano, Stanislaus, and Yolo counties, are expected to increase in population by nearly 3 million people by the year 2020 (California Commercial, Industrial, and Residential Real Estate Services Directory 2002). Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. For example, the General Plans for the cities of Stockton, Brentwood, Lathrop, Tracy and Manteca and their surrounding communities anticipate rapid growth for several decades to come. City of Manteca (2007) anticipates 21 percent annual growth through 2010 reaching a population of approximately 70,000 people. City of Lathrop (2007) expects to double its population by 2012, from 14,600 to approximately 30,000 residents. The anticipated growth will occur along both the I-5 and US-99 transit corridors in the east and Highway 205/120 in the south and west. Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions, particularly those which are situated away from waterbodies, will not require Federal permits, and thus will not undergo review through the section 7 consultation process with NMFS.

Increased urbanization also is expected to result in increased recreational activities in the region. Among the activities expected to increase in volume and frequency is recreational boating. Boating activities typically result in increased wave action and propeller wash in waterways. This potentially will degrade riparian and wetland habitat by eroding channel banks and mid-channel islands, thereby causing an increase in siltation and turbidity. Wakes and propeller wash also churn up benthic sediments thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation. This in turn would reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids and green sturgeon moving through the system. Increased recreational boat operation in the Delta is anticipated to result in more contamination from the operation of gasoline and diesel powered engines on watercraft entering the water bodies of the Delta.

C. Global Climate Change

The world is about 1.3 °F warmer today than a century ago and the latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature may rise by two or more degrees in the 21st century (Intergovernmental Panel on Climate Change [IPCC] 2001). Much of that increase likely will occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific (Noakes 1998). Using objectively analyzed data Huang and Liu (2000) estimated a warming of about 0.9 °F per century in the Northern Pacific Ocean.

Sea levels are expected to rise by 0.5 to 1.0 meters in the northeastern Pacific coasts in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This will cause increased sedimentation, erosion, coastal flooding, and permanent inundation of low-lying natural ecosystems (*e.g.*, salt marsh, riverine, mud flats) affecting salmonid PCEs. Increased winter precipitation, decreased snow pack, permafrost degradation, and glacier retreat due to warmer temperatures will cause landslides in unstable mountainous regions, and destroy fish and wildlife habitat, including salmon-spawning streams. Glacier reduction could affect the flow and temperature of rivers and streams that depend on glacier water, with negative impacts on fish populations and the habitat that supports them.

Summer droughts along the South Coast and in the interior of the northwest Pacific coastlines will mean decreased stream flow in those areas, decreasing salmonid survival and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest. Global warming may also change the chemical composition of the water that fish inhabit: the amount of oxygen in the water may decline, while pollution, acidity, and salinity levels may increase. This will allow for more invasive species to over take native fish species and impact predator-prey relationships (Peterson and Kitchell 2001, Stachowicz *et al.* 2002).

In light of the predicted impacts of global warming, the Central Valley has been modeled to have an increase of between 2 °C and 7 °C by 2100 (Dettinger *et al.* 2004, Hayhoe *et al.* 2004, Van Rheenen *et al.* 2004, Dettinger 2005), with a drier hydrology predominated by precipitation rather than snowfall. This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer snowmelt dominated system to a winter rain dominated system. It can be hypothesized that summer temperatures and flow levels will become unsuitable for salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This should truncate the period of time that suitable cold-water conditions exist below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold water pool developed from melting snow pack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Lake Shasta, could potentially rise above thermal tolerances for juvenile and adult salmonids (*i.e.* Sacramento River winter-run Chinook salmon and Central Valley steelhead) that must hold below the dam over the summer and fall periods.

VII. INTEGRATION AND SYNTHESIS

This section integrates the current conditions described in the environmental baseline with the effects of the proposed action and the cumulative effects of future actions. The purpose of this synthesis is to develop an understanding of the likely short term and long term response of listed species and critical habitat to the proposed project.

A. Summary of Current Conditions and Environmental Baseline

The *Status of Species* and *Environmental Baseline* sections show that past and present impacts to the San Joaquin River basin and South Delta have caused significant salmonid and green sturgeon habitat loss, fragmentation and degradation. This has significantly reduced the quality and quantity of freshwater rearing sites and the migratory corridors within the lower valley floor reaches of the San Joaquin River and the South Delta for these listed species. Additional loss of freshwater spawning sites, rearing sites, and migratory corridors have also occurred upstream of the South Delta in the upper mainstem and tributaries of the San Joaquin River.

Anthropogenic activities in the San Joaquin River watershed have contributed substantially to declines in Central Valley steelhead and southern DPS green sturgeon populations and have led to the extirpation of the Central Valley spring-run Chinook salmon populations endemic to the San Joaquin River Basin's watersheds (*e.g.*, completion of Friant Dam and the Kern and Friant canals in the late 1940s). Dam operations have reduced the extent of suitable water temperatures for over summering steelhead juveniles to the tailwaters immediately below these dams. In some cases the water temperatures reach incipient lethal temperatures only a few miles downstream of the dams. Alterations in the geometry of the South Delta channels, removal of riparian vegetation and shallow water habitat, construction of armored levees for flood protection, changes in river flow created by demands of water diverters (including pre-1914 riparian water right holders, CVP and SWP contractors, and municipal entities), and the influx of contaminants from agricultural and urban dischargers have substantially reduced the functionality of the action area's aquatic habitat. The proposed action, the installation and operation of the temporary barriers by DWR has been occurring for over 15 years (since 1991) and, thus, the effects of these past operations are also a part of the environmental baseline. The effects of past and present activities examined in the environmental baseline are expected to extend into the future for the duration of the proposed action's planned operations through year 2010. The proposed NPB is a new action that has not been a part of the baseline and, thus, will have affects that are cumulative to the baseline.

B. Summary of Effects of the Proposed Action

The originally proposed action (the construction of the three agricultural barriers and the HOR barrier) and the interrelated and interdependent activities associated with the action are expected to continue to affect the value of the action area as functional freshwater migration and rearing habitat for an additional 2 years. These effects are a continuation of the baseline effects that have occurred for the previous 17 years in the action area due to the ongoing nature of the operations of the temporary barriers. The portion of the proposed action involving installation of the three agricultural barriers has elements that will degrade existing functional habitat characteristics during the 8 months the barriers are in place each year (*i.e.*, free movement of fish, passage obstructions, increased predation, creation of lentic conditions, changes in channel flora and fauna populations, alterations in water quality parameters, *etc.*). The remaining 4 months of the year (December through March) will allow for some recovery of habitat conditions, including free movement of fish through the channels of the South Delta, and enhancement of water quality parameters related to flow patterns and tidal exchange. However, the impacts of the barrier placements each year will not be fully ameliorated by this short reprieve as the installation and removal are cyclical events and do not allow for a stable, natural habitat to become established in the action area.

The proposed NPB will not create permanent obstructions to fish passage through the channels of the South Delta and will have a minimal physical impact to the environment. It is designed as a temporary experiment to assess the efficacy of the air bubble curtain with acoustic and light deterrents to guide fish away from the Head of Old River channel bifurcation and retain them in the main channel of the San Joaquin River. The NPB will not affect the flow distribution or water quality parameters in the South Delta through its operations, nor will it alter water elevations or flow patterns in the remainder of the South Delta channels downstream of the Head of Old River location.

The installation of the HOR barrier has both positive and negative aspects for Central Valley steelhead. The barrier prevents most outmigrating fish originating in the San Joaquin Basin from entering the channels of the South Delta where predation is high, water quality is limiting, and migrating juveniles may become entrapped between the barriers. However, by keeping fish in the main channel of the San Joaquin River, the HOR barrier also limits the outmigrants to only one avenue of movement through the Delta waterways until they are below the Port of Stockton. This restriction to a single migratory rout can expose large proportions of a year-class of outmigrants to catastrophic environmental perturbations (sewage spills, train derailments, *etc.*) in this one channel. Fish remaining in the main channel of the San Joaquin between the Head of Old River and Turner Cut may also experience high levels of predation, diminished water quality in the vicinity of the City of Stockton Waste Water Treatment Plant and Port of Stockton, and reverse flows into the interior of the South Delta due to CVP and SWP pumping actions upon reaching Turner Cut. Nevertheless, the survival rate of fish remaining in the main channel of the San Joaquin River is considered to be higher than that of fish traveling through the waterways of the South Delta via Old River, based on statistical analysis completed for the VAMP studies (SJRGA 2006, 2007, Newman 2008).

When the HOR barrier is not installed, approximately half of the outmigrating steelhead smolts from the San Joaquin River basin are expected to follow the river's flow split into the channels of the South Delta as previously described. In the past, this event has typically occurred when flows were too high to safely install the barrier (flows > 5,000 cfs). These high flows are expected to have helped to move fish through the South Delta quickly and it is believed that predation risks were reduced due to the shorter residence time in the South Delta, although these hypotheses have not been statistically proven. If similar situations occur during the next 2 years of project implementation, steelhead smolts are expected to benefit under these conditions, as are other listed fish species. A unique situation occurred in 2008 with the implementation of a court order that prevented installation of the HOR barrier in order to protect delta smelt in the lower reaches of the Middle and Old Rivers. The HOR barrier was not installed, even though the ambient flows would have allowed it, while the three agricultural barriers were installed to benefit agricultural diverters in the South Delta. Under this arrangement, steelhead smolts from the San Joaquin River basin were able to enter the South Delta channels and were subjected to the full effects of the three agricultural barriers without the benefits of higher flows. NMFS anticipates that survival of fish that enter Old River under these conditions will be lower than those that stay in the San Joaquin River. Due to a lack of biological studies and monitoring in this area, it is impossible to quantify, or even estimate a) the percentage of the juvenile steelhead population that will enter the HOR after the barriers have been installed; b) the level of mortality that will befall the fish that enter the HOR as compared to those that remain in the San Joaquin River; and c) the long term impacts to the Central Valley steelhead DPS resulting from the unknown level of increased mortality suffered by the San Joaquin Basin steelhead that enter the Head of Old River. There is the potential that reduced survival of emigrating smolts through the South Delta could diminish the proportion of fish reaching the ocean to a large enough extent that this impact would be carried forward to reduce adult escapement numbers several years into the future, but again there is a lack of scientific data to allow NMFS to make this determination. Targeted studies designed to determine the fate of listed salmonids and green sturgeon entering the South Delta through the Head of Old River and the specific effects of the South Delta TBP are expected to be implemented in the near future. These studies will supply the scientific data necessary to determine the extent and significance of the impacts of the South Delta Barriers.

The proposed NPB is partially in response to the situation which occurred in 2008 when the HOR barrier, which is intended to protect emigrating salmonids in the San Joaquin River, was intentionally not installed in order to protect Delta smelt. The NPB is designed to allow water to enter the Old River channel at the head, thus meeting the flow requirements for Delta smelt farther downstream on Old and Middle rivers, while also serving as a deterrent to emigrating salmonids that would try to enter the Old River channel during their downstream emigration, and guiding them to remain in the main channel of the San Joaquin River through the Delta. Additional benefits of the NPB are realized farther downstream when the fish encounter the channels of Turner and Columbia cuts, and Middle and Old rivers, which diverge from the main channel of the San Joaquin River. Under typical conditions, the flow of water in these channels has a net movement towards the export facilities in the south west corner of the Delta. It is expected that net flows in these channels will be more positive compared to the typically net negative flows seen under the temporary barrier conditions. This is due to the movement of water into the Head of Old River, which supplies a portion of the CVP and SWP exports, and therefore somewhat relieves the draw of water from the north to supply the export demands. Fish benefit from this reduction in southward-moving water flow as it reduces their vulnerability to diversion into the channels of the South Delta from the north. The interior of the South Delta has low survival rates for salmonids, and those that survive are likely to be entrained by the export facilities.

The proposed action also affects individuals from the Central Valley spring-run Chinook salmon ESU, the Sacramento River winter-run Chinook salmon ESU, and the Southern DPS green sturgeon that are present in the waters of the South Delta. Although no critical habitat for spring-run and winter-run Chinook salmon exists currently in the South Delta, the small numbers of these fish that do end up in the South Delta rely on the physical and biological attributes of the South Delta channels to provide rearing and migrational functions for their survival. Critical habitat in the South Delta has been proposed for the Southern DPS of green sturgeon, and the elements of the critical habitat present in the south Delta are considered necessary for the continuing survival of the Southern DPS of green sturgeon. The proposed action is expected to impact individuals of these listed ESUs and DPSs in the South Delta in manners similar to those previously described for the Central Valley steelhead. The three agricultural barriers fragment habitat and restrict free movement of fish in these channels and elevate their risk of predation or mortality from other sources (*i.e.*, poor water quality, contaminants, *etc.*).

1. Sacramento River Winter-Run Chinook Salmon

Individuals from the Sacramento River winter-run Chinook salmon ESU are the least affected due to their earlier migration timing. Based on the CVP/SWP salvage data (Reclamation 2007), nearly 97 percent of the annual winter-run Chinook salmon salvage has occurred in the South Delta by the April installation date of the temporary barriers. Therefore, roughly 3 percent of the annual winter-run Chinook salmon presence in the South Delta can be affected by the operations of the temporary barriers. Average annual winter-run Chinook salmon salvage during the months of April, May, and June is roughly 260 fish. The average JPE for the last 5 years (excluding 2007) is approximately 1.5 million fish. Based on these estimates, the percentage of juvenile winter-run Chinook salmon exposed to the effects of the TBP is 0.017 percent of the average annual juvenile production.

2. Central Valley Spring-Run Chinook Salmon

Individuals from the Central Valley spring-run Chinook salmon ESU are more likely to be affected than the winter-run Chinook salmon ESU due to the later peak in their outmigration. Based on the salvage data from the CVP/SWP, approximately two thirds of the annual spring-run Chinook salmon salvage occurs in April. Only 20 percent of the annual salvage occurs prior to April. Therefore, nearly 80 percent of the spring-run Chinook salmon presence in the South Delta waterways will occur during the operation of the temporary barriers. The average number of spring-run Chinook salmon sized fish salvaged during the months of April, May, and June is approximately 13,500 fish. The estimated JPE for spring-run Chinook salmon over the past 5 years (excluding 2007) is nearly 2,000,000 fish. Based on these estimates, the percentage of juvenile spring-run Chinook salmon exposed to the effects of the TBP is 0.68 percent of the average annual juvenile production.

3. Central Valley steelhead

Outmigrating steelhead smolts from the Sacramento River basin and other tributaries outside of the San Joaquin River Basin account for most of the nearly 1,000 total fish (clipped and unclipped) salvaged at the CVP/SWP facilities during the months of April, May, and June. Hatchery fish (clipped) are more prevalent in April than they are in May and June. It is believed that San Joaquin River Basin fish make up a greater percentage of the wild fish in late spring recovered at the CVP/SWP facilities as a result of the VAMP flow increases in the basin stimulating the steelhead to emigrate from their natal streams. Estimates for juvenile production in the San Joaquin River Basin are unavailable due to a lack of data from the basin. Since typically less than a dozen steelhead smolts per year are captured in the Mossdale Monitoring Trawls, juvenile production does not appear to be very high in the basin. In contrast, the Sacramento River basin is estimated to have an annual wild fish production of approximately 181,000 smolts per year.

4. Southern DPS North American Green sturgeon

Juvenile and sub-adult life stages of the Southern DPS of green sturgeon rear year round in the waters of the Delta and are therefore expected to be exposed to the effects of the temporary barriers over their entire eight-month installation period. Like San Joaquin River basin steelhead, there are no reliable estimates of juvenile production, and no estimates of the number of individuals rearing in the South Delta action area, so the population level of exposure is unknown. Those green sturgeon juveniles and sub-adults that do enter the action area are likely to experience habitat fragmentation, reductions in free movement through the channels of the South Delta, and potential entrapment behind the barriers during the periods of seasonal operations.

C. Combined Effects

The steelhead population in the San Joaquin River basin is susceptible to activities in the South Delta which impact the ability of adults and juveniles to successfully move through this region. The three agricultural barriers are expected to create impediments to free fish movement and passage in the waterways of the South Delta, leading to increased rates of mortality due to higher predation, degradation of water quality, and prolongation of migration through the system without sufficient rearing capacity. These negative impacts diminish the ability of the population to respond to larger environmental stressors in the watershed. Small, discrete subpopulations, such as those steelhead populations found in the San Joaquin River basin, are highly susceptible to extirpation from ongoing actions which decrease the spawning success rate, rearing capacity or ability of the individual fish to migrate to and from the ocean effectively. Currently the larger population of Central Valley steelhead is in decline and the role of these smaller populations becomes important in maintaining spatial and genetic diversity within the DPS. They may serve as sources of genetic variability, spatially separated population pools to minimize the risk of local extinctions, and sources of new founder populations in the event of a local extinction event.

The impacts described in the Cumulative Effects section are expected to further diminish the functional value of steelhead critical habitat within the action area. For instance, increased demands for water, whether for agricultural purposes or for domestic consumption are expected to continue in the South Delta. The region's pre-1914 riparian water right holders have the senior rights to divert water in the action area, and are not expected to decrease their water diversion entitlements for environmental purposes. Likewise, regional urban development is expected to continue, although the rate of development may slow due to economic pressures in the area. Therefore, the demand for domestic and municipal water supplies diverted from the South Delta and San Joaquin River Basins are expected to increase to meet these demands in future years, although the rate of increase may moderate in the near term due to economic trends. As urban development increases in the area over the next three years, the ability to modify or enhance the riparian zone of the South Delta channels will be lessened in response to flood management needs for urbanized areas (*i.e.*, Ripon, Manteca, and Mountain House areas). This circumstance will perpetuate the already degraded status of the critical habitat in the action area, add to the adverse effects of the proposed action, and reduce the potential of future environmental restoration actions such as setback levees or flood benches along the river channels.

D. Summary

The combined effects of the proposed action will have mixed consequences on listed fish in the South Delta action area. The three agricultural barriers will seasonally diminish or degrade critical habitat for Central Valley steelhead, proposed critical habitat for the Southern DPS of green sturgeon, as well as habitat for Central Valley spring-run Chinook salmon and Sacramento River winter-run Chinook salmon in the action area without any foreseeable beneficial effects for the listed fish species. The presence and operations of the barriers will also increase the extent of mortality related to predation, delays in migration to the ocean, and exposure to degraded water conditions. These effects are expected to occur primarily during the 8 months of the barrier installation season. The remaining 4 months of the year will see only residual effects associated with habitat alterations incurred during the 8 months of barrier operation (*i.e.*, changes in macroinvertebrate density and populations, extent of riparian and emergent vegetation levels, *etc.*).

With regards to the proposed operation of the TBP, the spring HOR barrier, when installed, will have both positive and negative aspects associated with its operations as previously described. It will only be installed for a period of 31 days, typically from mid-April to mid-May, after which it is removed from the channel. However, if the current prohibitions on its installation due to the Wanger Court decision and the USFWS' OCAP biological opinion continue, the beneficial aspects of the HOR barrier will not be realized. The fall HOR barrier is installed in the September to November time frame at CDFG's request to help ameliorate low DO conditions in the Stockton DWSC adjacent to the Port of Stockton, which is a benefit to San Joaquin River basin fish. Due to the fish passage notch cut into the top of the barrier, delay of adult steelhead should be minimal for those fish migrating up river through the waterways of the South Delta. The implementation of the NPB experiment will address the potential for using alternative technologies to guide fish away from the Old River channel when the HOR barrier is not installed. If this experiment is successful in demonstrating that the air bubble curtain technology is able to guide fish away from the Head of Old River, then the conflict between Delta smelt needs and the needs of San Joaquin River basin fish may have a resolution.

The proposed implementation of the TBP is expected to reduce the functionality of the principal constituent elements of the designated critical habitat for Central Valley steelhead in the South Delta. This will occur on a seasonal basis that will last for the three years of the proposed action. Passage for emigrating steelhead will still be possible through the mainstem channel of the San Joaquin River but will be diminished within the South Delta channels due to the presence of the three agricultural barriers. While the majority of Central Valley steelhead generally migrate through the action area prior to the installation of the temporary barriers, the survival of fish emigrating later in the spring when the barriers are installed is expected to be reduced by the effects of the TBP, particularly for those fish that reach the area after the HOR barrier is removed in mid- to late-May. The proposed action should not have any demonstrable effect on fish leaving the San Joaquin River basin prior to April, when the barriers will not be in place. The 1-year implementation of the NPB experiment is not anticipated to have any permanent impacts on critical habitat for Central Valley steelhead or on proposed critical habitat for the Southern DPS of green sturgeon.

For Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead (Sacramento River origins) populations that are drawn into the South Delta and exposed to the operations of the barriers, mortality is expected to increase. However, these fish will have already been drawn into the South Delta by actions other than the proposed barrier actions (*i.e.*, SWP and CVP pumping) and mortality is expected to be substantial regardless of the location of the individual fish once it enters the South Delta. The proportion of the total juvenile production for these Central Valley populations lost to the effects of the barriers is expected to be extremely low, based on the current estimates, and thus should not have any demonstrable effect on these populations. The 1-year implementation of the NPB experiment is not expected to have any demonstrable effect on Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, or Central Valley steelhead from the Sacramento River basin.

The magnitude and significance of the effects of the TBP on San Joaquin Basin origin populations of Central Valley steelhead is impossible to quantify due to a lack of monitoring and scientific data in this area. Current unknowns include the proportion of each year class that will be exposed to the barriers and the level of mortality for those fish that do encounter the barriers. However, the limited information that is available indicates that the annual installation and operations of the TBP is likely to reduce the survival rate of those fish that are exposed to the full effects of the barriers. Given the baseline condition of greatly reduced populations remaining in the San Joaquin tributaries, and the likely continued decline in habitat conditions due to the cumulative effects of future actions in the action area, there is a potential for project related reductions in survival to have lingering effects on the overall likelihood of survival and recovery of one or more of the tributary populations remaining in the San Joaquin Basin. In contrast, the 1-year NPB experiment is not anticipated to have demonstrable adverse effects on the San Joaquin River Basin steelhead population above that which currently exists in the baseline. It may in fact, reduce the impacts on the San Joaquin River basin steelhead by reducing the number of fish that enter the South Delta channels through the Head of Old River and improving downstream hydrodynamics in the vicinity of Turner and Columbia cuts and Old and Middle rivers in relation to export actions.

Given this unknown potential for impacts, the TBP may have a substantial effect on the remaining populations of Central Valley steelhead in the San Joaquin River basin. The concepts of the VSP require that these small populations be protected from extirpation to retain both genetic and spatial diversity within the larger DPS of Central Valley steelhead. Losses of these small sub-populations reduce the overall viability of the larger Central Valley DPS. It is likely that these small San Joaquin populations receive significant supplementation from the larger Sacramento River populations through straying by the overwhelmingly dominant Sacramento Basin populations. However, straying from these small populations back into the larger Central Valley steelhead population may also provide for the flow of unique genetic traits back into the overall gene pool for the Central Valley.

The HOR barrier is designed to reduce the impacts of the TBP by preventing emigrating fish from entering Old River and encountering the higher losses associated with this route through the Delta to the ocean. The intentional prohibition of the HOR barrier installation for Delta smelt protection increases the risk to the steelhead populations in the San Joaquin River basin. The NPB experiment has the potential to provide relief to this impact by allowing water, but not steelhead, to move into the channel of Old River. It is also important to note that these San Joaquin Basin populations have endured the current level of effects from the proposed TBP for over 15 years, and that these levels of impacts are only expected to continue for an additional 2 years before the expiration of this Opinion. The proposed NPB experiment will potentially reduce this impact for the current year, and if successful, can be implemented next year too. This will provide additional protection to San Joaquin River basin steelhead for the remainder of the current opinion.

VIII. CONCLUSION

After reviewing the best available scientific and commercial information, the current status of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and the Southern DPS of North American green sturgeon, the environmental baseline, the effects of the proposed Temporary Barriers Project as amended, and the cumulative effects, it is NMFS' biological opinion that the TBP as amended, is not likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, or the Southern DPS of North American green sturgeon, nor will it result in the destruction or adverse modification of designated critical habitat for Central Valley steelhead in the San Joaquin Delta.

After reviewing the best scientific and commercial data available, including the current status of proposed Southern DPS of North American green sturgeon critical habitat, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is NMFS' conference opinion that the proposed Temporary Barriers Project is not likely to destroy or adversely modify proposed critical habitat for the Southern DPS of North American green sturgeon.

IX. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS as an act which kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not the purpose of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

Although some measures described below are expected and intended to avoid, minimize, or monitor the take of North American green sturgeon, the section 9 prohibitions against taking of listed species and terms and conditions of the incidental take statement in this biological opinion will not apply to North American green sturgeon until a final section 4(d) rule becomes effective.

The measures described below are non-discretionary, and must be undertaken by the Corps so that they become binding conditions of any grant or permit, as appropriate, for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps (1) fails to assume and implement the terms and conditions or (2) fails to require DWR to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Corps and/or DWR must report the progress of the action and its impact on the species to NMFS as specified in the incidental take statement (50 CFR §402.14(i)(3)).

A. Amount or Extent of Take

NMFS anticipates that the proposed action will result in the incidental take of individuals from the Sacramento River winter-run Chinook salmon ESU, the Central Valley spring-run Chinook salmon ESU, the Central Valley steelhead DPS, and the Southern DPS of North American green sturgeon. Incidental take associated with this action is expected to be in the form of mortality, harm, or harassment of juvenile Sacramento River winter-run Chinook salmon, juvenile Central Valley spring-run Chinook salmon, adult and juvenile Central Valley steelhead and juveniles from the Southern DPS of North American green sturgeon, resulting from the construction of the temporary barriers in spring due to crushing from the deposited rock barrier material, harassment from the generation of underwater noise associated with the construction process during installation and removal of the barriers, increased vulnerability to predation during the construction process and barrier operations, and the impedance of free migratory movements within the South Delta during the operational period of the temporary barriers. Incidental take of juvenile Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon is expected to occur during the period form April 1 to June 30, when individuals from these two ESUs could potentially be present in the action area. Similarly, both adult and juvenile Central Valley steelhead are expected to be present during the April 1 through June 30 time period. Adult Central Valley steelhead are also expected to be present during the fall (September through November) to varying extents during their upstream spawning movements into the San Joaquin River basin. Juveniles and sub-adults from the Southern DPS of North American green sturgeon are expected to be present in the action area year round and would overlap with the 8-month operational period of the TBP (April through November).

NMFS cannot, using the best available information, accurately quantify the anticipated incidental take of individual listed fish because of the variability and uncertainty associated with the population size of each species, annual variations in the timing of migration, and uncertainties regarding individual habitat use of the TBP area. However, it is possible to designate ecological surrogates for the extent of take anticipated to be caused by the TBP, and to monitor those surrogates to determine the level of take that is occurring. The two most appropriate ecological surrogates for the extent of take caused by the TBP are the total size of the physical footprint of each barrier to be constructed and the period of time that each barrier will be in place each year.

Ecological Surrogates

- The analysis of the effects of the proposed TBP anticipates that the installation of the four barriers will directly impact approximately 63,000 square feet of channel bottom (1.45 acres). The HOR barrier spring installation footprint will have dimensions of approximately 250 feet by 85 feet (19,125 square feet), while the footprint of its fall installation will be slightly smaller at 225 feet by 55 feet (12,375 square feet). The ORT barrier will have a footprint of approximately 250 feet by 60 feet (15,000 square feet). The GLC barrier will have a footprint of approximately 300 feet by 50 feet (15,000 square feet). The MR barrier will have a footprint of approximately 270 feet by 50 feet (13,500 square feet). The NPB will have a footprint of approximately 2,200 square feet of channel bottom (370 feet long by 6 feet wide).

- The analysis of the effects of the proposed TBP anticipates that the spring HOR barrier will not be fully closed or operated prior to April 15 and the barrier will be completely removed by May 15, unless the fishery agencies (CDFG, USFWS, NMFS) request it remain operating until May 31. Initiation of installation and operation of the fall HOR barrier will at the discretion of the CDFG, and regardless of its installation date, the fall HOR barrier shall be completely removed no later than November 30. The ORT barrier will not be fully closed or operated prior to April 15 and will be breached by October 31 and completely removed by November 7. However, if the fall HOR barrier is installed, the ORT barrier may remain operating through November and will be completely removed by November 30. The MR barrier will not be fully closed or operated prior to April 15 and will be breached by October 31 and completely removed by November 7. However, if the fall HOR barrier is installed, the Middle River barrier may remain operating through November and will be completely removed by November 30. Provided that the spring HOR barrier is installed for that year, the GLC barrier shall not be fully closed or operated until April 15. If the spring HOR barrier is not installed, then construction on the GLC barrier will not begin until May 15, and will not be fully closed and operated until June 1. The GLC barrier will be breached by October 31 and completely removed by November 7. However, if the fall HOR barrier is installed, then the GLC barrier may remain in operation through November and will be completely removed by November 30. Construction of the NPB will not commence prior to April 6 and will be removed following completion of the VAMP experiment. NMFS anticipates that this will be no later than May 31, with complete removal of the NPB infrastructure within 2 weeks of the completion of the VAMP experiment.

If these ecological surrogates are not met and maintained, the proposed TBP will be considered to have exceeded anticipated take levels, triggering the need to reinitiate consultation on the TBP.

B. Effect of the Take

In the accompanying biological opinion, NMFS determined that this level of anticipated take is not likely to result in jeopardy to the listed anadromous fish species.

C. Reasonable and Prudent Measures

NMFS believes that the following reasonable and prudent measures are necessary and appropriate to minimize take of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and the Southern DPS of North American green sturgeon resulting from implementation of the action.

1. The Corps and DWR shall avoid or minimize construction related impacts associated with the implementation of the TBP upon juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS of North American green sturgeon within the action area of the TBP.

2. The Corps and DWR shall develop and implement a fisheries monitoring program which examines the movements and survival of listed fish through the channels of the South Delta.

3. The Corps and DWR shall implement fisheries monitoring programs to examine predation effects associated with the TBP.

4. The Corps and DWR shall develop an adaptive management protocol to reconcile future operations of the TBP with fisheries needs in the South Delta.

D. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Corps and DWR must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline prescribed reporting/monitoring requirements. These terms and conditions are non-discretionary:

1. **The Corps and DWR shall avoid or minimize construction-related impacts associated with the implementation of the TBP upon juvenile Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and Southern DPS of North American green sturgeon within the action area of the TBP.**

    a. The barriers shall be constructed at the following locations: Old River near the CVP intake facilities (ORT; 37.8100 N, -121.5427 W), Middle River (MR; 37.8856 N, -121.4799 W), Grant Line Canal (GLC; 37.8198 N; -121.4477 W), and Old River near Mossdale (HOR; 37.8082 N, -121.3287 W). The NPB shall be installed at the following location adjacent to the Head of Old River (37.8080 N, -121.3274 W). Any variance from these locations will constitute the need to reinitiate consultation with NMFS.

    b. Construction impacts shall be confined to the minimum area necessary to complete TBP barriers. The installation of the four barriers will impact approximately 63,000 square feet of channel bottom (1.45 acres). The HOR barrier spring installation footprint has dimensions of approximately 250 feet by 85 feet (19,125 square feet), while the footprint of its fall installation is slightly smaller at 225 feet by 55 feet (12,375 square feet). The ORT barrier has a footprint of approximately 250 feet by 60 feet (15,000 square feet). The GLC barrier has a similar sized footprint of 300 feet by 50 feet (15,000 square feet). The MR barrier has a footprint of 270 feet by 50 feet (13,500 square feet). The allowable size of the footprint must be within 10 percent of these listed values. The NPB will have a footprint of approximately 2,200 square feet of channel bottom (370 feet long by 6 feet wide).

    c. Stockpiling of construction materials including rocks, gravel, flexible cement matting, portable equipment, vehicles and supplies, including chemicals and chemical containers, shall be restricted to designated construction staging areas and exclusive of the riparian areas. Staging of these materials may begin on or after April 1 for the spring installation of the barriers.

    d. In water construction may commence on or after April 7 for the spring installation of the barriers. Complete removal of the barriers will be completed by November 30 of each season.

    e. The NPB will be installed on or after April 6, 2009, and removed immediately upon completion of the VAMP experiment. NMFS will allow removal of the barrier through June 15 to accommodate the potential for a May 31 end to the VAMP experiment, plus 2 weeks to remove the structure and pilings.

f. All heavy equipment shall be fueled, maintained, and stored at a safe distance from any adjacent waterways. Standard construction best management practices (BMPs), as described in the current California Department of Transportation Construction Site Best Management Practices Manual (Caltrans 2003), shall be implemented so that no oil, grease, fuel or other fluids contaminate the waterways around the work sites.

g. The trailer housing the power supply and equipment to operate the NPB shall be placed on the berm adjacent to the Head of Old River installation site (northeast corner of Stewart Tract), where rock for the temporary barrier is typically stored. A spill prevention and control plan that includes actions to contain any fuel or chemical leaks shall be implemented at all times during the operation of the NPB. The containment area shall be sized to accommodate the entire volume of fuel or hazardous materials stored on site so that no leakage to the river can occur should the storage containers rupture and spill their contents.

h. Erosion control measures that prevent soil or sediment from entering the river during construction, or as a result of construction, shall be implemented and maintained throughout construction, or as needed as described in the Caltrans Construction Site BMP Manual.

i. Any Chinook salmon, steelhead or green sturgeon found dead or injured within 0.1 mile upstream or downstream of construction sites during barrier installation shall be reported immediately to NMFS via fax:

   Attention Supervisor, NMFS Sacramento Area Office
   Fax at (916) 930-3623)
   or by phone at: (916) 930-3600.

   A follow-up written notification shall also be submitted NMFS which includes the date, time, and location that the carcass or injured specimen was found, a color photograph, the cause of injury or death, if known, and the name and affiliation of the person who found the specimen. Written notification shall be submitted to:

   Supervisor, Sacramento Area Office
   National Marine Fisheries Service
   650 Capitol Mall, Suite 8-300
   Sacramento, California 95814

   Any dead specimen(s) should be placed in a cooler with ice and held for pick up by NMFS personnel or an individual designated by NMFS to do so.

j. Within 30 days of completing any construction activity associated with the TBP, DWR shall submit a report to the Corps and NMFS describing the work that was performed, the starting and ending dates of the construction actions, any observed adverse effects to aquatic habitats and their duration (*i.e.*, increased suspended sediment levels or turbidity, instances of pollution, unusual animal behaviors in adjacent waters, *etc.*), any problems encountered during construction activities, and any adverse effects to Chinook salmon, steelhead, or green sturgeon associated with the construction activities that was not previously considered.

2. **The Corps and DWR shall develop and implement a fisheries monitoring program which examines the movements and survival of listed fish through the channels of the South Delta.**

    a. The Corps and DWR shall develop this study with the input of biologists from NMFS and acquire all necessary State and Federal research and collection permits prior to implementation of the study.

    b. Studies shall focus on fish movement and survival through the waterways of the Delta which contains the temporary barriers and those that feed into the South Delta region. NMFS recommends the utilization of acoustic telemetry techniques to maximize the efficiency of data collection for fish movements and the estimates of survival rates within the instrumented waterways.

    c. Acoustic receivers shall be installed by spring of 2008 in the waterways of the South Delta. Fish studies shall commence by water year 2008-2009.

    d. The fisheries monitoring protocol for the NPB experiment shall be implemented according to the project description. A Technical Memorandum shall be made available to NMFS as soon as possible following completion of the NPB study, but no later than June 30, 2009, as stated in the project description.

    e. Annual data reports shall be sent to NMFS by January 30th of each year through 2011 at the address in term and condition 1(g). A final report summarizing findings shall be sent to NMFS by December 31, 2011.

3. **The Corps and DWR shall implement fisheries monitoring programs to examine predation effects associated with the TBP.**

    a. The Corps and DWR shall develop this study with the input of biologists from NMFS and acquire all necessary State collection permits prior to implementation of the study.

    b. DWR shall tag predatory fish with acoustic tags which are captured within the vicinity of the temporary barriers or collected at the SWP fish collection facilities. Species to be tagged include striped bass, largemouth bass, Sacramento pike minnow, and white catfish.

    c. Predatory fish shall be released within the South Delta at or near the location of their capture and their movements monitored for the duration of the acoustic tag's battery life.

    d. Movements and behavior of the predatory fish species shall be correlated with the barrier operations, delta hydraulics during the study period, and listed fish presence.

e. Studies of predatory fish shall be implemented by the summer of 2008.

f. Annual data reports shall be sent to NMFS by January 30th of each year through 2011 at the address in term and condition 1(g). A final report summarizing findings shall be sent to NMFS by December 31, 2011.

4. The Corps and DWR shall develop an adaptive management protocol to reconcile future operations of the TBP with fisheries needs in the South Delta.

a. DWR, in coordination with NMFS staff, shall develop operational protocols to reduce entrainment of San Joaquin River basin Central Valley steelhead when the HOR barrier has not been installed during the spring period.

b. Actions taken to reduce entrainment of delta smelt shall be coordinated with NMFS to reduce adverse impacts to listed salmonids and green sturgeon in the South Delta region.

X. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations include discretionary measures that the Corps and DWR can take to minimize or avoid adverse effects of a proposed action on a listed species or critical habitat.

1. The Corps and DWR should implement biotechnical measures in place of traditional revetment techniques should any of their projects' riprap begin to cause scour and require additional bank stabilization.

2. The Corps and DWR should conduct or fund studies to help quantify fish losses at water diversions, and prioritize fish screen projects for future funding.

3. The Corps and DWR should continue to work cooperatively with other State and Federal agencies, private landowners, governments, and local watershed groups to identify opportunities for cooperative analysis and funding to support salmonid habitat restoration projects within the Delta region.

XI. REINITIATION OF CONSULTATION

This concludes the reinitiation of formal consultation on construction and operations of the South Delta Temporary Barriers Program through year 2010. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded, (2) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered, (3) the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in the biological opinion, or (4) a new species is listed or critical habitat designated that may be affected by the identified action. In instances where the amount or extent of incidental take is exceeded, formal consultation shall be reinitiated immediately.

The Corps may request NMFS to confirm the conference opinion on the proposed critical habitat of the Southern DPS of North American green sturgeon as a biological opinion if the proposed critical habitat designation becomes final. The request must be in writing. If NMFS reviews the proposed action and finds that there have been no significant changes to the action or in the information used during the conference, NMFS will confirm the conference opinion as a biological opinion for the Temporary Barriers Project, and no further section 7 consultation will be necessary.

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Appendix A: Table

Table 1: Historical operating schedule of the South Delta Temporary Barriers.

Middle River Barrier (MR)

	Installation				Removal		
Year	Started	Closed	Completed	Notched	Started	Breached	Completed
1987			15-May		End Sept		End Sept
1988	26-May		28-May		23-Sept		23-Sept
1989			12-April		26-Sept		26-Sept
1990			16-April		29-Sept		29-Sept
1991	4-April		5-April		27-Sept		27-Sept
1992	8-April		10-April		28-Sept		29-Sept
1993	14-June		17-June		23-Sept		24-Sept
1994	23-April		25-April		29-Sept		5-Oct
1995	8-Aug		11-Aug		10-Oct		10-Oct
1996	18-May		20-May		29-Sept		29-Sept
1997	3-April		7-April		27-Sept		28-Sept
1998	(vii)						
1999	15-May		18-May		29-Sept		
2000	4-April		6-April		1-Oct		7-Oct
2001	20-April		23-April		12-Nov		13-Nov
2002	10-April		15-April		20-Nov	20-Nov	23-Nov
2003	12-April	15-April	23-April	17-Sept	7-Nov	8-Nov	10-Nov
2004	9-April	12-April	13-April	23-Sept	9-Nov	10-ov	12-Nov
2005	10-May	12-May	17-May	15-Sept	7-Nov	8-Nov	9-Nov
2006	5-July	7-July	8-July	1-Oct	17-Nov	18-Nov	20-Nov
2007	7-April	10-April	10-April				

Table 1 continued:

Old River near Tracy (ORT)

	Installation				Removal		
Year	Started	Closed	Completed	Notched	Started	Breached	Completed
1987							
1988							
1989							
1990							
1991	14-Aug		30-Aug		26-Sept		13-Oct (i)
1992	15-April		01-May		30-Sept		09-Oct (ii)
1993	12-May		01-June		27-Sept		6-Oct
1994	22-April Culverts tied open 5/18 to 6/1		24-April		26-Sept		10-Oct
1995	3-Aug		8-Aug		27-Sept		6-Oct
1996	12-May		10-June (iii)		29-Sept		16-Oct
1997	8-April		17-April		30-Sept		7-Oct
1998	(vii)						
1999	15-May		28-May		28-Sept		8-Oct
2000	4-April		16-April		1-Oct		7-Oct
2001	23-April		26-April		13-Nov	14-Nov	26-Nov
2002	1-April		18-April		16-Nov	16-Nov	29-Nov
2003	1-April	14-April	22-April	17-Sept	13-Nov	15-Nov	25-Nov
2004	1-April	15-April	20-April	10-Sept	8-Nov	8-Nov	1-Dec
2005	9-May	31-May	6-June	15-Sept	8-Nov	10-Nov	30-Nov
2006	7-July	17-July	31-July	1-Oct	13-Nov	16-Nov	8-Dec
2007	2-April	18-Apri;	23-April				

Table 1 continued:

Grant Line Canal Barrier (GLC)

	Installation			Flashboards	Removal		
Year	Started	Closed	Completed	Adjusted	Started	Breached	Completed
1987							
1988							
1989							
1990							
1991							
1992							
1993							
1994							
1995							
1996	17-June		10-July		2-Oct		15-Oct
1997	21-May		4-June		26-Sept		15-Oct
1998	(vii)						
1999	15-May		3-June		23-Sept		6-Oct
2000	19-May		1-June		1-Oct		7-Oct
2001	2-May		9-May		11-Nov	12-Nov	25-Nov
2002	1-April		12-June		14-Nov	16-Nov	25-Nov
2003	1-April (partial) 9-June (complete)	11-June	23-April (partial) 17-June (complete)	16-sept	10-Nov	12-Nov	25-Nov
2004	1-April (partial) 2-June (complete)	9-April (partial) 5-June (complete)	28-April (partial) 9-June (Complete)	9-Sept	11-Nov	12-Nov	6-Dec
2005	2-May	14-July	18-july	14-July & 14-Sept	7-Nov	15-Nov	30-Nov
2006	7-July	20-July	26-July	20-July& 1-Oct	14-Nov	21-Nov	6-Dec
2007	9-April (partial) 27-April (complete)	17-April (partial) 10-May (complete)	17-April (partial) 11-May (complete)	17-April (partial) 10-May (complete)			

Table 1 continued:

Spring Head of Old River Barrier (HOR) (v)

	Installation			Removal		
Year	Started	Closed	Completed	Started	Breached	Completed
1987						
1988						
1989						
1990						
1991						
1992	15-April		23-April@ 4ft 26-April @ 6ft	2-June		8-June
1993						
1994	21-April		23-April @ 10ft	18-May		20-May
1995	(vii)					
1996	6-May		11-May	16-May		3-Sept (iv)
1997	9-April		16-April	15-May		19-May
1998	(vii)					
1999	(vii)					
2000	5-April		16-April	19-May		2-June
2001	17-April		26-April	23-May		30-May
2002	2-April		18-April	22-May	24-May	7-June
2003	1-April	15-April	21-April	16-May	18-May	3-June
2004	1-April	15-April	21-April	19-May	24-May	10-June
2005	(vii)					
2006	(vii)					
2007	11-April	20-April	26-April	19-May	22-May	6-June

Table 1 continued:

Fall Head of Old River Barrier (HOR)

	Installation				Removal		
Year	Started	Closed	Completed	Notched	Started	Breached	Completed
1987	9-Sept		11-Sept				28-Nov
1988	22-Sept		28-Sept				2-Dec
1989	27-Sept		28-Sept		27-Nov		30-Nov
1990	10-Sept		11-Sept				27-Sept
1991	9-Sept		13-Sept		22-Nov		27-Nov
1992	8-Sept		11-Sept		30-Nov		4-Dec
1993	8-Nov (vii)		11-Nov		3-Dec		7-Dec
1994	6-Sept		8-Sept		28-Nov		30-Nov
1995	(vii)						
1996	30-Sept		3-Oct		18-Nov		22-Nov
1997	(viii)						
1998	(vii)						
1999	(viii)						
2000	27-Sept		7-Oct		27-Nov		8-Dec
2001	24-Sept		6-Oct		22-Nov	22-Nov	2-dec
2002	24-Sept		4-Oct		11-Nov	12-Nov	21-Nov
2003	2-Sept	15-Sept	18-Sept	16-Sept	3-Nov	4-Nov	13-Nov
2004	7-Sept	27-Sept	29-Sept	28-Sept	1-Nov	2-Nov	12-Nov
2005	19-Sept	28-Sept	30-Sept	29-Sept	7-Nov	8-Nov	15-Nov
2006	(viii)						
2007							

(i) Barriers notched on Sept. 28, 1991. Construction resumed on Oct. 10 and finished on Oct 13, 1991.
(ii) Barrier notched on Sept. 30, 1992. Construction resumed on Oct.2, 1992 and finished on Oct. 9, 1992.
(iii) Construction was delayed on 5/17/96 and resumed on 6/5/96 due to high San Joaquin River flows.
(iv) Barrier was breached on 5/16/96 on an emergency basis, but complete removal was not accomplished until 9/3/96 after the Corps demanded compliance with the permit.
(v) Barrier was installed in previous years under different programs.
(vi) Barrier installation delayed due to high San Joaquin River flows.
(vii) Barrier not installed due to high San Joaquin River flows.
(viii) Barrier not installed upon CDFG's request.

Table 8: The annual occurrence of juvenile Southern DPS of North American green sturgeon at the CVP and SWP fish collection facilities in the South Delta. (Adams et al, (2007), CDFG 2002)

Year	State Facilities		Federal Facilities	
	Salvage Numbers	Numbers per 1000 acre feet	Salvage Numbers	Numbers per 1000 acre feet
1968	12	0.0162		
1969	0	0		
1970	13	0.0254		
1971	168	0.2281		
1972	122	0.0798		
1973	140	0.1112		
1974	7313	3.9805		
1975	2885	1.2033		
1976	240	0.1787		
1977	14	0.0168		
1978	768	0.3482		
1979	423	0.1665		
1980	47	0.0217		
1981	411	0.1825	274	0.1278
1982	523	0.2005	570	0.2553
1983	1	0.0008	1475	0.653
1984	94	0.043	750	0.2881
1985	3	0.0011	1374	0.4917
1985	0	0	49	0.0189
1987	37	0.0168	91	0.0328
1988	50	0.0188	0	0
1989	0	0	0	0
1990	124	0.0514	0	0
1991	45	0.0265	0	0
1992	50	0.0332	114	0.0963
1993	27	0.0084	12	0.0045
1994	5	0.003	12	0.0068
1995	101	0.0478	60	0.0211
1996	40	0.0123	36	0.0139
1997	19	0.0075	60	0.0239
1998	136	0.0806	24	0.0115
1999	36	0.0133	24	0.0095
2000	30	0.008	0	0
2001	54	0.0233	24	0.0106
2002	12	0.0042	0	0
2003	18	0.0052	0	0
2004	0	0	0	0
2005	16	0.0044	12	0.0045
2006	39	0.0078	324	0.1235

Figure 1b. Location of the proposed Non Physical Barrier at the Head of Old River. Red line shows approximate location of bubble curtain. Blue arrows indicate direction of river flow. Lighter green color indicates shallower water depth, darker green indicates deeper water, and blue indicates deepest water

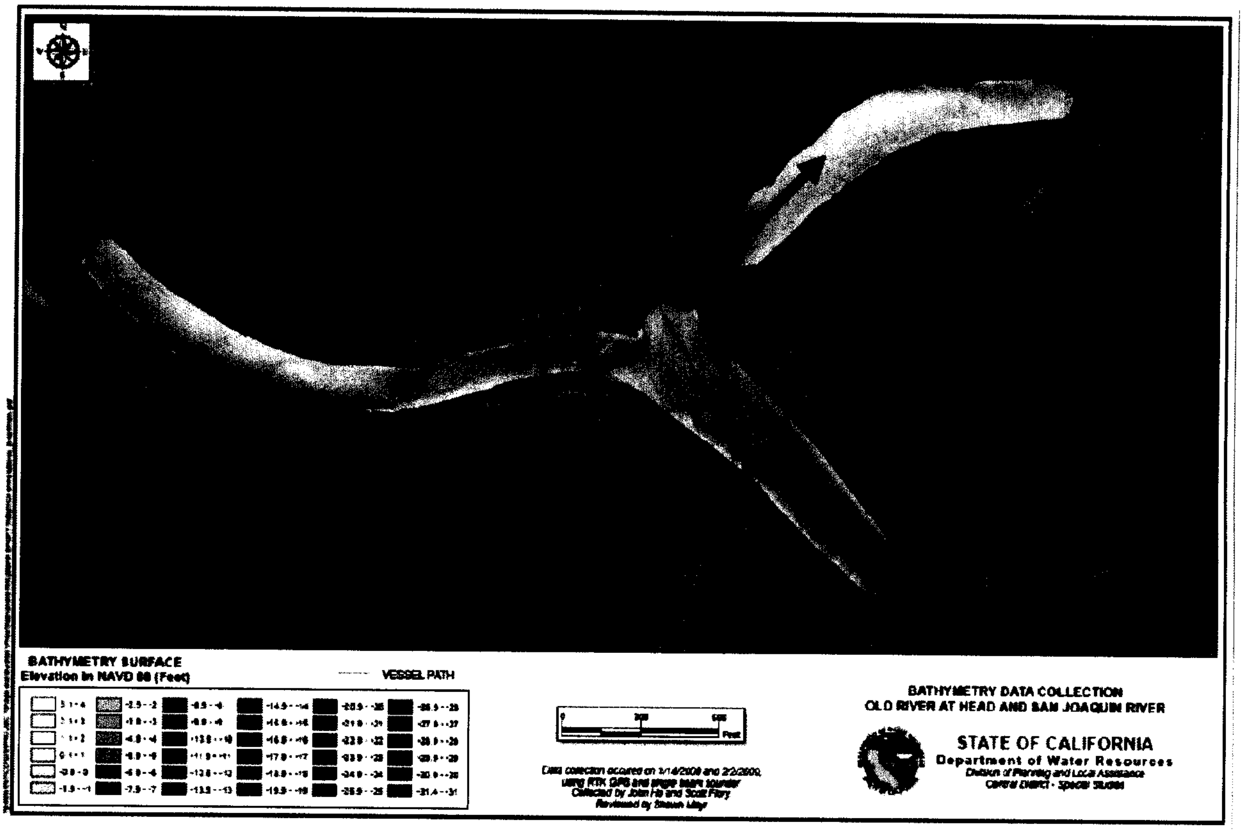

Figure 2: Plan view of proposed Non Physical Barrier

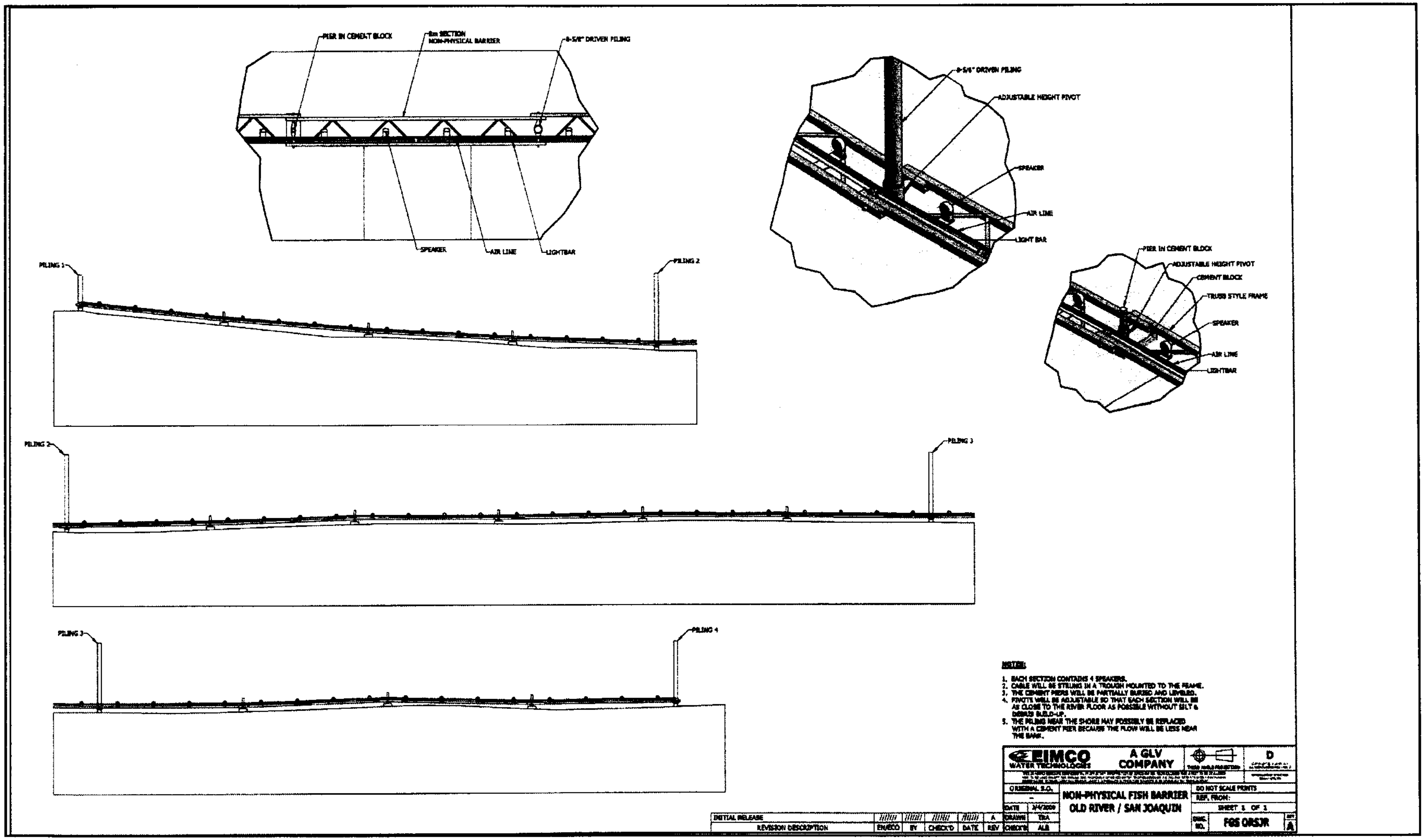

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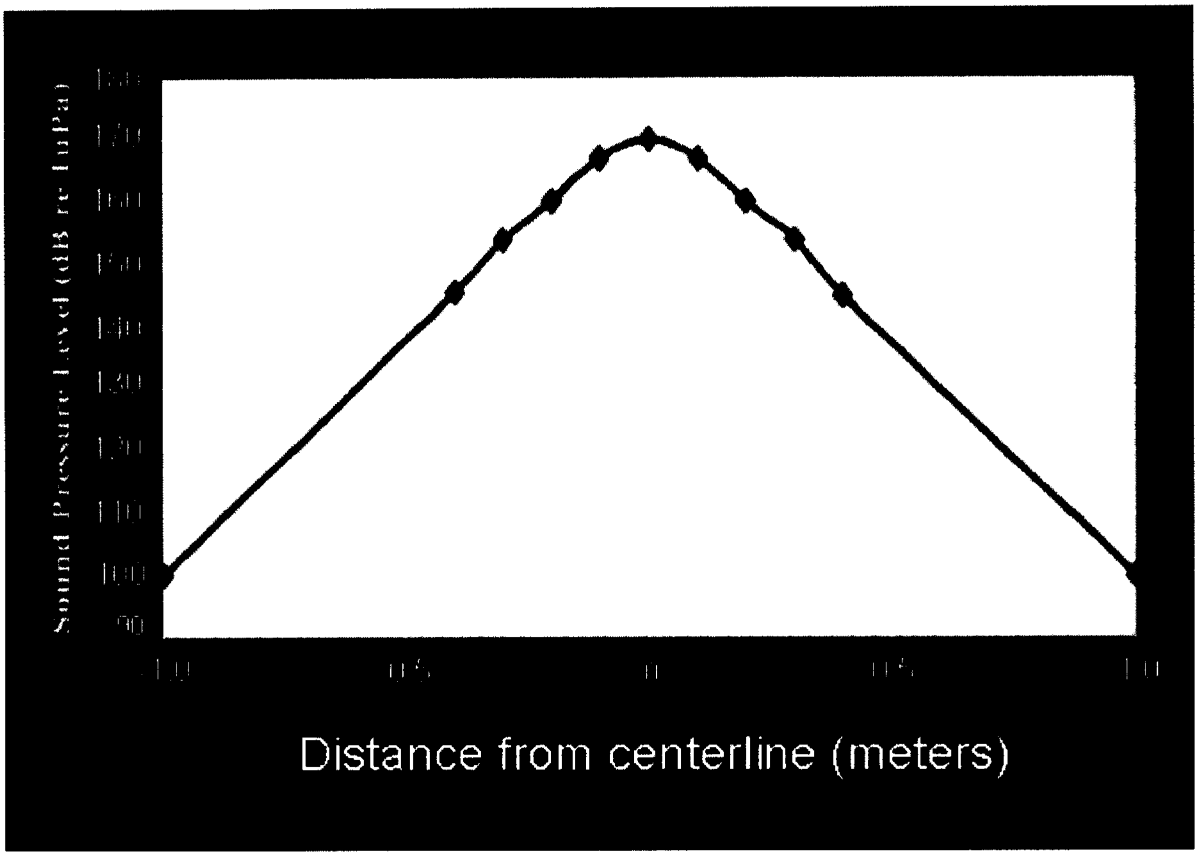
Figure 3: Decay of sound in horizontal direction for the centerline of the Non Physical Barrier showing containment of the acoustic signal from the sound generator within the bubble curtain.



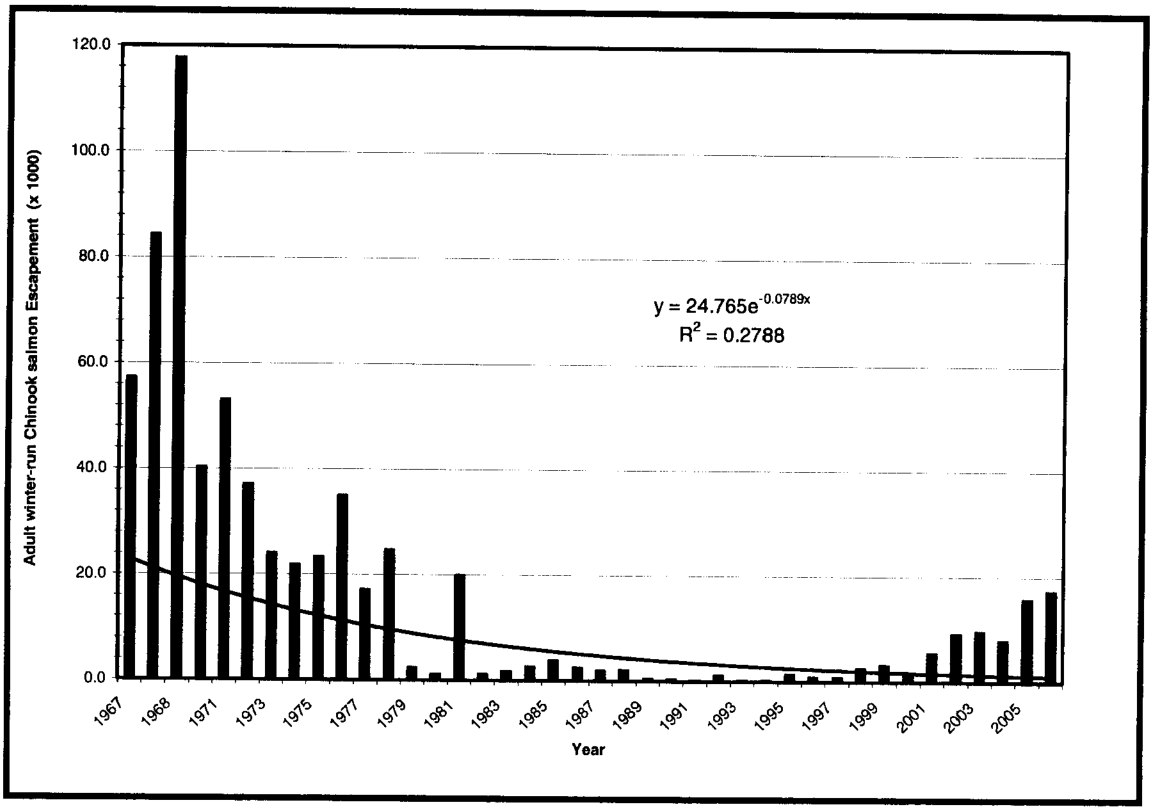


Figure 4:
Annual estimated Sacramento River winter-run Chinook salmon escapement population 1967 through 2006. Sources: PFMC 2002, 2004, CDFG 2004a, NMFS 1997
Trendline for figure 4 is an exponential function: $Y=24.765\ e^{-0.0789x}$, $R^2=0.2788$.

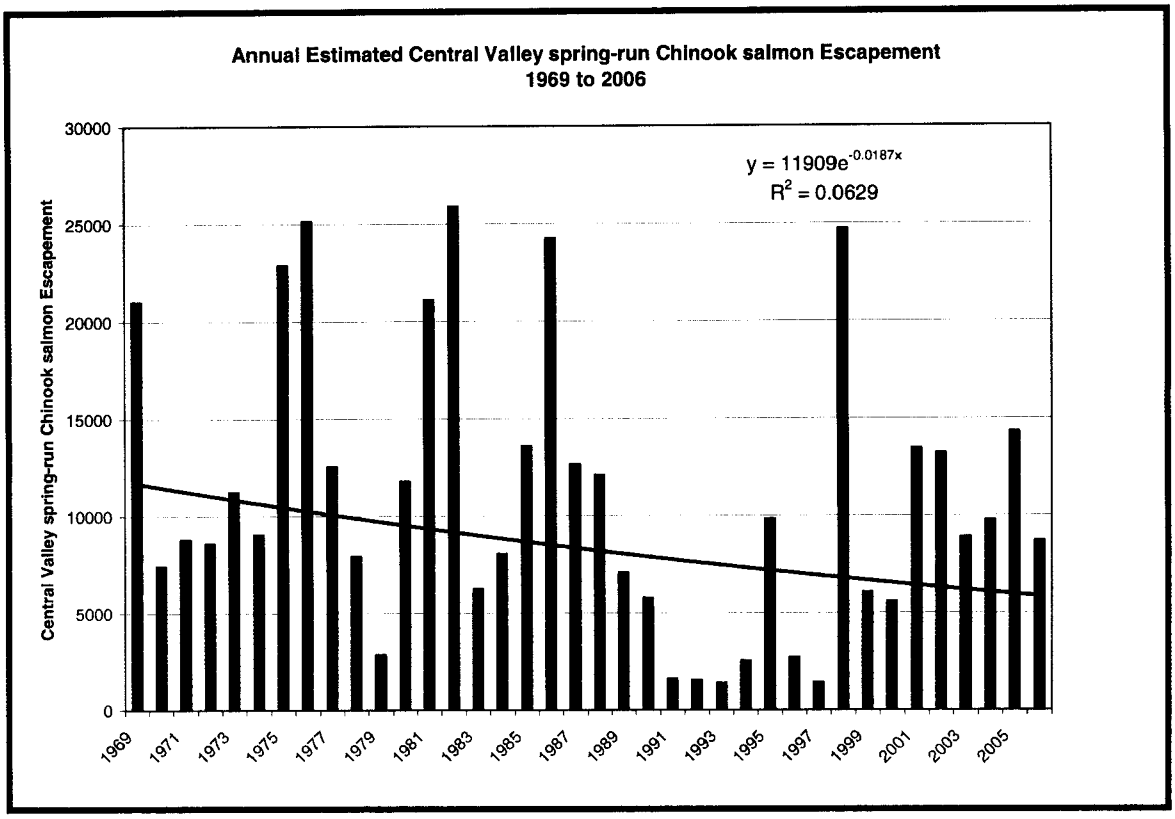
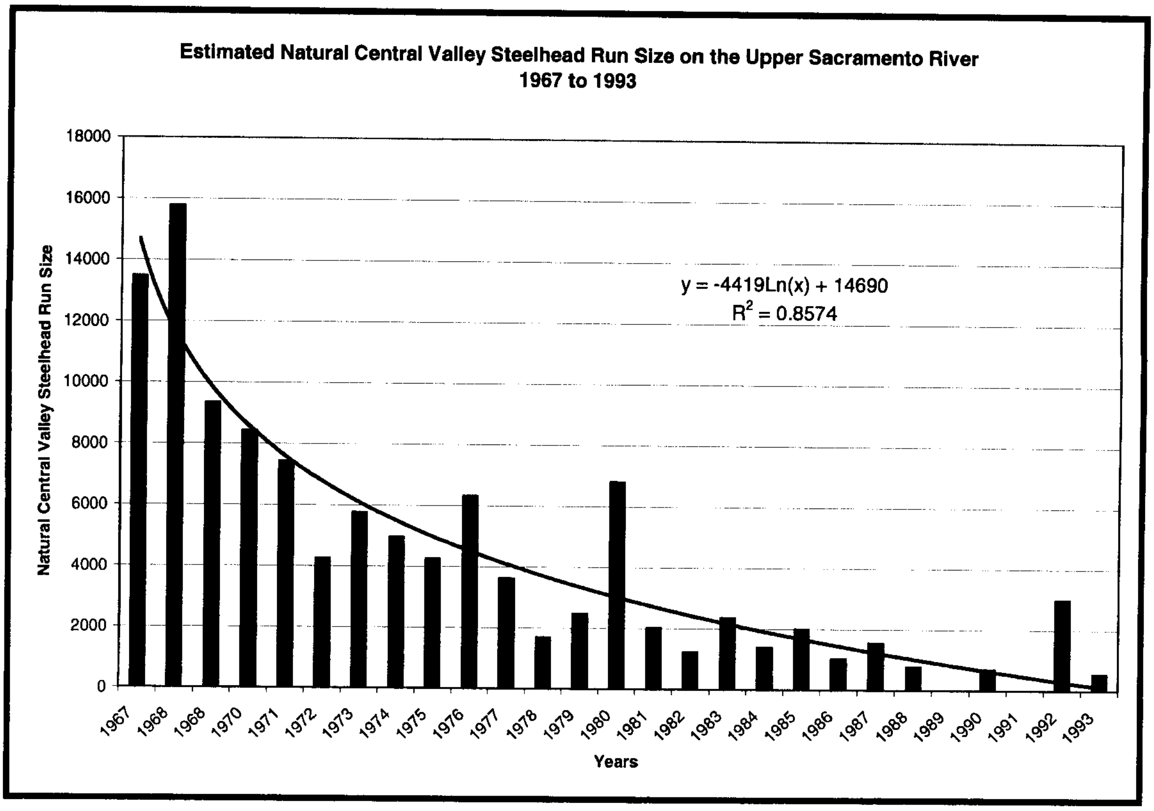


Figure 5:
Annual estimated Central Valley spring-run Chinook salmon escapement population for the Sacramento River watershed for years 1969 through 2006.
Sources: PFMC 2002, 2004, CDFG 2004b, Yoshiyama 1998, GrandTab 2006.
Trendline for figure 5 is an exponential function: $Y=11909\ e^{-0.0187}$, $R^2 = 0.0629$.



Note: Steelhead escapement surveys at RBDD ended in 1993

Figure 6:
Estimated Central Valley natural steelhead escapement population in the upper Sacramento River based on RBDD counts.
Source: McEwan and Jackson 1996.
Trendline for Figure 6 is a logarithmic function: Y= -4419 Ln(x) + 14690 R^2= 0.8574

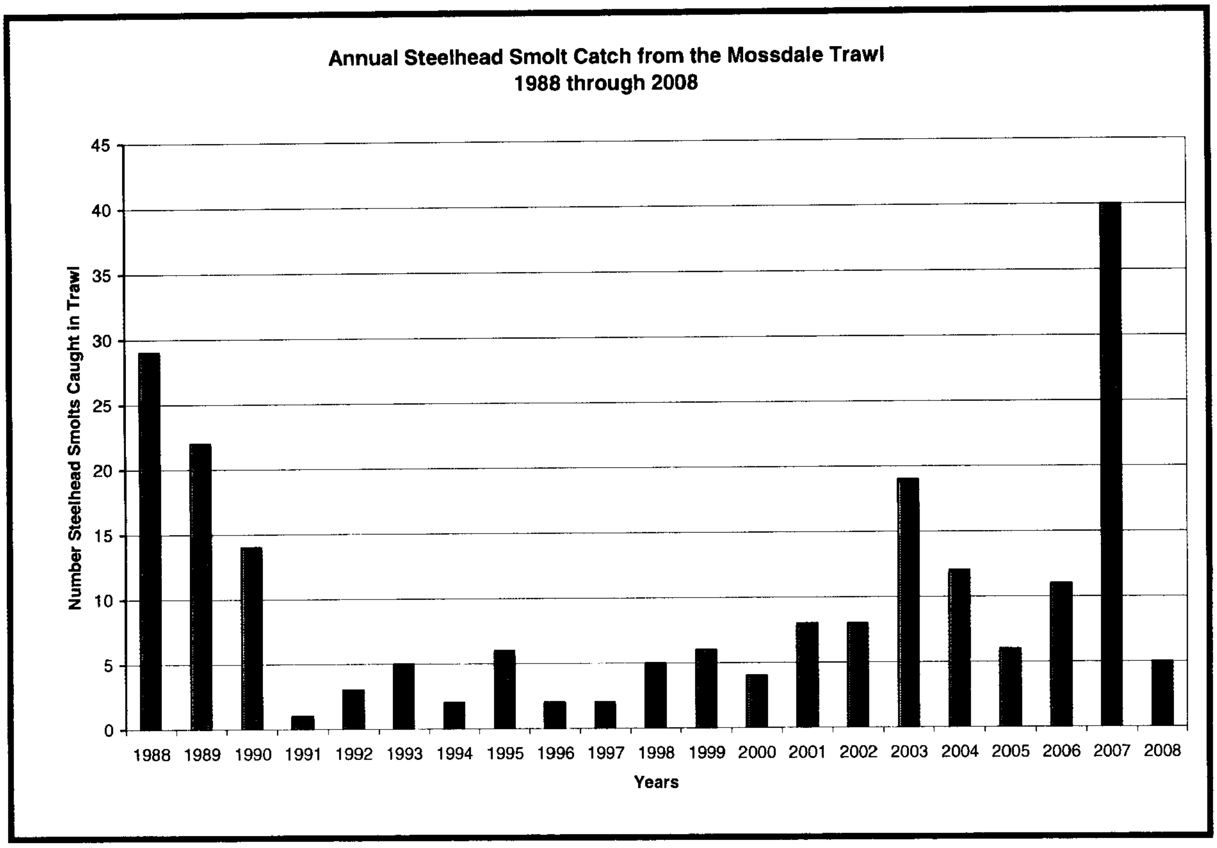


Figure 7: Annual number of Central Valley steelhead smolts caught while Kodiak trawling at the Mossdale monitoring location on the San Joaquin River (Marston 2004, SJRG 2007, Speegle USFWS 2008 pers comm).

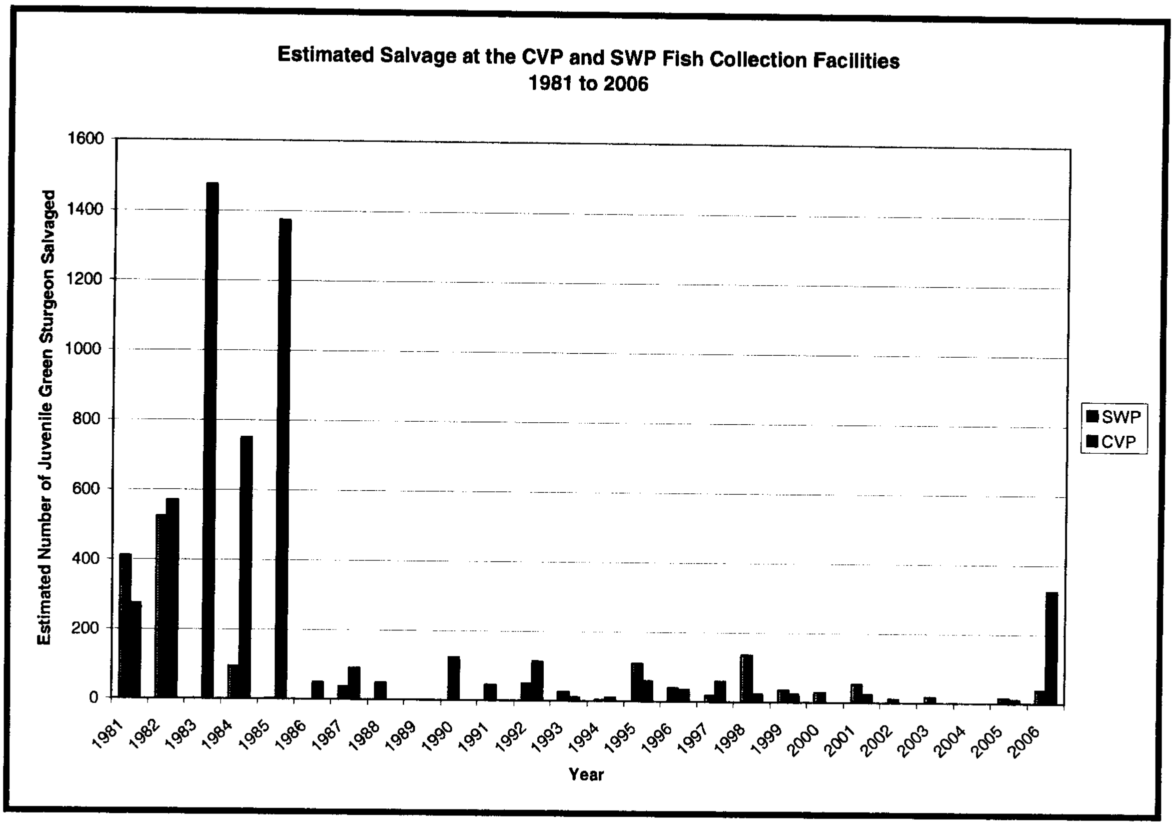


Figure 8a: Estimated number of North American green sturgeon (Southern DPS) salvaged from the State Water Project and the Central Valley Project fish collection facilities.

Sources: Beamesderfer *et al.*, 2007, CDFG 2002, Adams *et al.* 2007.

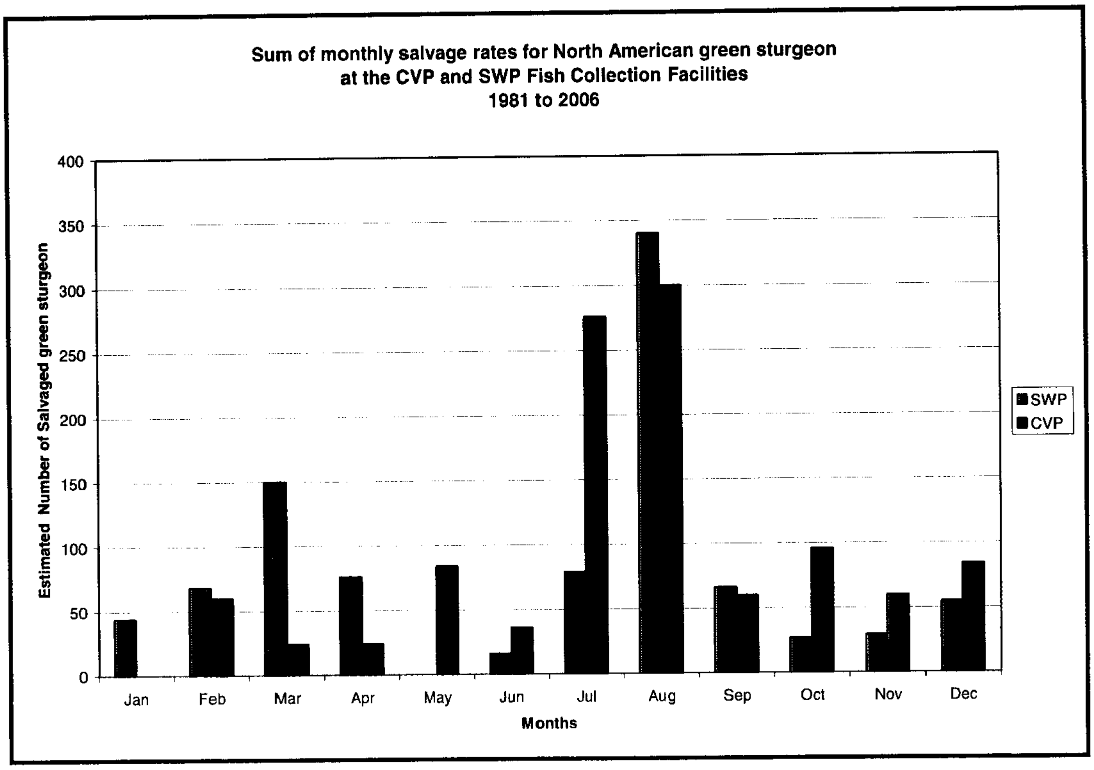


Figure 8b: Estimated number of North American green sturgeon (southern DPS) salvaged monthly from the State Water Project and the Central Valley Project fish collection facilities.

Source: CDFG 2002, unpublished CDFG records.

Enclosure 2

Magnuson-Stevens Fishery Conservation and Management Act

ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

I. IDENTIFICATION OF ESSENTIAL FISH HABITAT

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended (U.S.C. 180 *et seq.*), requires that Essential Fish Habitat (EFH) be identified and described in Federal fishery management plans (FMPs). Federal action agencies must consult with NOAA's National Marine Fisheries Service (NMFS) on any activity which they fund, permit, or carry out that may adversely affect EFH. NMFS is required to provide EFH conservation and enhancement recommendations to the Federal action agencies.

EFH is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purposes of interpreting the definition of EFH, "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means habitat required to support a sustainable fishery and a healthy ecosystem; and, "spawning, breeding, feeding, or growth to maturity" covers all habitat types used by a species throughout its life cycle. The proposed project site is within the region identified as EFH for Pacific salmon in Amendment 14 of the Pacific Salmon FMP.

The Pacific Fishery Management Council (PFMC) has identified and described EFH, Adverse Impacts and Recommended Conservation Measures for salmon in Amendment 14 to the Pacific Coast Salmon FMP (PFMC 1999). Freshwater EFH for Pacific salmon in the California Central Valley includes waters currently or historically accessible to salmon within the Central Valley ecosystem as described in Myers *et al.* (1998), and includes the San Joaquin Delta (Delta) hydrologic unit (*i.e.*, number 18040003. Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), and Central Valley fall-/late fall-run Chinook salmon (*O. tshawytscha*) are species managed under the Salmon Plan that occur in the Delta unit.

Factors limiting salmon populations in the Delta include periodic reversed flows due to high water exports (drawing juveniles into large diversion pumps), loss of fish into unscreened agricultural diversions, predation by introduced species, and reduction in the quality and quantity of rearing habitat due to channelization, pollution, riprapping, *etc.* (Dettman *et al.* 1987; California Advisory Committee on Salmon and Steelhead Trout 1988, Kondolf *et al.* 1996a, 1996b). Factors affecting salmon populations in Suisun Bay include heavy industrialization within its watershed and discharge of wastewater effluents into the bay. Loss of vital wetland habitat along the fringes of the bay reduce rearing habitat and diminish the functional processes that wetlands provide for the bay ecosystem.

A. Life History and Habitat Requirements

Pacific Salmon

General life history information for Central Valley Chinook salmon is summarized below. Information on Sacramento River winter-run and Central Valley spring-run Chinook salmon life histories is summarized in the preceding biological opinion for the proposed project (Enclosure 1). Further detailed information on Chinook salmon Evolutionarily Significant Units (ESUs) are available in the NMFS status review of Chinook salmon from Washington, Idaho, Oregon, and California (Myers *et al.* 1998), and the NMFS proposed rule for listing several ESUs of Chinook salmon (63 FR 11482).

Adult Central Valley fall-run Chinook salmon enter the Sacramento and San Joaquin Rivers from July through December and spawn from October through December while adult Central Valley late fall-run Chinook salmon enter the Sacramento and San Joaquin Rivers from October to April and spawn from January to April (U.S. Fish and Wildlife Service [FWS] 1998). Chinook salmon spawning generally occurs in clean loose gravel in swift, relatively shallow riffles or along the edges of fast runs (NMFS 1997).

Egg incubation occurs from October through March (Reynolds *et al.* 1993). Shortly after emergence from their gravel nests, most fry disperse downstream towards the Delta and into the San Francisco Bay and its estuarine waters (Kjelson *et al.* 1982). The remaining fry hide in the gravel or station in calm, shallow waters with bank cover such as tree roots, logs, and submerged or overhead vegetation. These juveniles feed and grow from January through mid-May, and emigrate to the Delta and estuary from mid-March through mid-June (Lister and Genoe 1970). As they grow, the juveniles associate with coarser substrates along the stream margin or farther from shore (Healey 1991). Along the emigration route, submerged and overhead cover in the form of rocks, aquatic and riparian vegetation, logs, and undercut banks provide habitat for food organisms, shade, and protect juveniles and smolts from predation. These smolts generally spend a very short time in the Delta and estuary before entry into the ocean. Whether entering the Delta or estuary as fry or juveniles, Central Valley Chinook salmon depend on passage through the Delta for access to the ocean.

II. PROPOSED ACTION

The proposed action is described in section II (*Description of the Proposed Action*) of the preceding biological opinion for endangered Sacramento River winter-run Chinook salmon, threatened Central Valley spring-run Chinook salmon, Central Valley steelhead (*O. mykiss*), threatened southern DPS of North American green sturgeon, and critical habitat for Central Valley steelhead (Enclosure 1).

III. EFFECTS OF THE PROJECT ACTION

The effects of the proposed action on salmonid habitat are described at length in section V (*Effects of the Action*) of the preceding biological opinion, and generally are expected to apply to Pacific salmon EFH.

IV. CONCLUSION

Based on the best available information, NMFS believes that the proposed reinitiation of the South Delta Temporary Barriers Program and extension of the program through 2010 may adversely affect EFH for Pacific salmon during its normal long-term operations.

V. EFH CONSERVATION RECOMMENDATIONS

NMFS recommends that the following conservation measures be implemented in the project action area, as addressed in Appendix A of Amendment 14 to the Pacific Coast Salmon Plan (PFMC 1999).

Riparian Habitat Management–In order to prevent adverse effects to riparian corridors, the U.S. Army Corps of Engineers (Corps) should:

- Maintain riparian management zones of appropriate width along Old River;
- Reduce erosion and runoff into waterways within the project area; and
- Minimize the use of chemical treatments within the riparian management zone to manage nuisance vegetation along the levee banks.

Bank Stabilization–The installation of riprap or other streambank stabilization devices can reduce or eliminate the development of side channels, functioning riparian and floodplain areas and off channel sloughs. In order to minimize these impacts, the Corps should:

- Use vegetative methods of bank erosion control whenever feasible. Hard bank protection should be a last resort when all other options have been explored and deemed unacceptable;
- Determine the cumulative effects of existing and proposed bio-engineered or bank hardening projects on salmon EFH, including prey species, before planning new bank stabilization projects; and
- Develop plans that minimize alterations or disturbance of the bank and existing riparian vegetation.

Conservation Measures for Construction/Urbanization–Activities associated with urbanization (*e.g.*, building construction, utility installation, road and bridge building, and storm water discharge) can significantly alter the land surface, soil, vegetation, and hydrology and subsequently adversely impact salmon EFH through habitat loss or modification. In order to minimize these impacts, the Corps and the applicant should:

- Plan development sites to minimize clearing and grading;

- Use Best Management Practices in building as well as road construction and maintenance operations such as avoiding ground disturbing activities during the wet season, minimizing the time disturbed lands are left exposed, using erosion prevention and sediment control methods, minimizing vegetation disturbance, maintaining buffers of vegetation around wetlands, streams and drainage ways, and avoid building activities in areas of steep slopes with highly erodible soils. Use methods such as sediment ponds, sediment traps, or other facilities designed to slow water runoff and trap sediment and nutrients; and

- Where feasible, reduce impervious surfaces.

Wastewater/Pollutant Discharges-Water quality essential to salmon and their habitat can be altered when pollutants are introduced through surface runoff, through direct discharges of pollutants into the water, when deposited pollutants are resuspended (*e.g.*, from dredging), and when flow is altered. Indirect sources of water pollution in salmon habitat includes run-off from streets, yards, and construction sites. In order to minimize these impacts, the Corps and the applicant should:

- Monitor water quality discharge following National Pollution Discharge Elimination System requirements from all discharge points;

- For those waters that are listed under Clean Water Act section 303 (d) criteria (*e.g.*, the Delta), work with State and Federal agencies to establish total maximum daily loads and develop appropriate management plans to attain management goals; and

- Establish and update, as necessary, pollution prevention plans, spill control practices, and spill control equipment for the handling and transport of toxic substances in salmon EFH (*e.g.*, oil and fuel, organic solvents, raw cement residue, sanitary wastes, *etc.*). Consider bonds or other damage compensation mechanisms to cover clean-up, restoration, and mitigation costs.

VI. STATUTORY REQUIREMENTS

Section 305 (b) 4(B) of the MSA requires that the Federal lead agency provide NMFS with a detailed written response within 30 days, and 10 days in advance of any action, to the EFH conservation recommendations, including a description of measures adopted by the lead agency for avoiding, minimizing, or mitigating the impact of the project on EFH (50 CFR §600.920[j]). In the case of a response that is inconsistent with our recommendations, the Corps must explain its reasons for not following the recommendations, including the scientific justification for any disagreement with NMFS over the anticipated effects of the proposed action and the measures needed to avoid, minimize, or mitigate such effects.

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